ORADEA URBAN BUS SYSTEM ENERGY EFFICIENCY ANALYSIS

LIBOR L., CSUZI I.
Oradea Transport Local SA
laszlo.libor@otl.ro, laszlolibor@yahoo.com, istvancsuzi@yahoo.com, dir.gen@otl.ro

ABSTRACT: Brief description of Public Transport Company and network in Oradea, passenger statistics, analysis of energy consumption, passenger/kilometer parameter evaluation, compare liquid fuel and electricity consumption, cost reduction, optimization

1. NTRODUCTION

The Public Transport Company in Oradea (OTL SA) currently operates five tram and twenty urban bus lines, covering the city's main transport axes [2]. In addition to the local public transport organization and exploitation OTL SA provides the public transport services for two metropolitan-area villages (Sânmartin and Borş) and administratively associated villages of them on six bus lines, and operates an international cross-border bus route (between Oradea/Romania and Biharkeresztes/Hungary). The study aims to compare the power consumption of trams and buses in perspective of distances and the transported passengers. Increasing energy efficiency and attractiveness of public transport for passengers. The increase of energy efficiency and increase of transported passenger clearly leads to an improvement of economic indicators.

The analyzed period regarding to the energy efficiency are 2014 and 2015. Yearly, monthly, weekly and daily analyzes. In order to analyze the passenger flow evaluation we are monitoring the number of passengers in each hour of days. Based on this analyzes we can determine and optimize therequired vehicle capacity.

The bus and tram mileage, covered distancesare gained from two applications. These applications are: "Fleet Management" software (which generates data based on GPS tracking) and an "in-house" developed software that is specifically designed to evaluate the company's bus fleet (mileage, consumption data and the calculation of worked hours).

Passenger flow data is extracted from two applications. The E-ticketing systemfor E-Card validation, as well as the"Fleet Management" application for paper based ticket validation. Based on the comparison and analyze of these datawe can estimate the required vehicle capacity for different periods of the day.

The electric energy consumption data (weekly, monthly and yearly), are available separately for each electric rectifier (power) station. The diesel fuel consumption data for the analyzed period, is available from the "in-house" bus fleet analyzing software. The software is using a consumption database with exact measurement for all the bus-lines and all type of busses of the fleet. The Diesel fuel consumption is calculated based on these data.

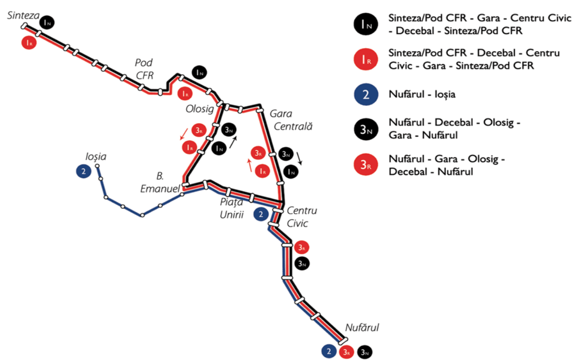
To compare our liquid fuel and electric power consumption we need a common denominator [3]. The Tone of oil equivalent (TOE) is a unit of energy defined as the amount of energy released by burning one tone of crude oil. It is approximately 42 gigajoules, although as different crude oils have different calorific values, the exact value is defined by convention; several slightly different definitions exist. The International Energy Agency defines one tone of oil equivalent (TOE) to be equal to 41.868 GJ (11.63 megawatt hours). Different energy value standard comparisons are included in Table 1.

Table 1 - Energy value standard comparison in TOE

Electric Energy	1 MWh = 0.086
Thermal Energy	1 G-Cal = 0.1
Natural Gas	1000 Nm³ = 0.805
Black Oil	1 to = 0.95
Filtered Oil	1 to = 0.97
Fuel	1 to = 1.05
Diesel	1 to = 1.015

2. CASE STUDY: THE URBAN BUS NETWORK IN ORADEA

Urban bus network map show a very good coverage of Public Transport accessibility.



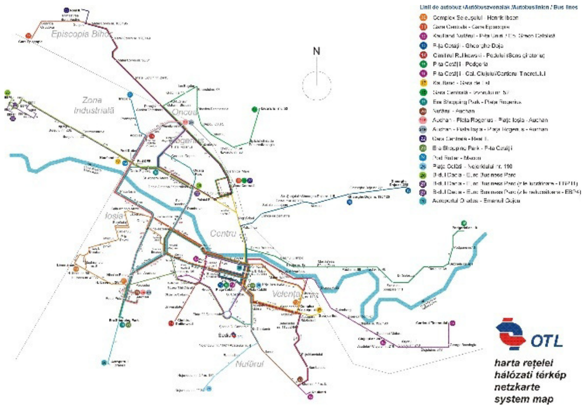


Fig.1 - Tram and Bus network in Oradea (2016)

The public transport system analysis challenge how to be compared the tram and bus. The comparison is intended to analyze the tram or the bus per passenger and per kilometer for the use of energy more efficient, cost efficiency in this case is not studied (vehicle and maintenance, human resource cost will collect for economic studies).

PASSENGER FLOW DATA ANALYSIS: Comparing the 2014 and 2015 annual data from the main bus lines [4], (e.g. line 12 and17),we can see two peaks (rush hours) every day, in the morning and in the afternoon. Outside of rush hours the provided vehicle capacity is higher than the necessary. On other bus lines (e.g.line 18 or 19), the number of passengers are not visibly changing. On these lines for the whole day is true the statement that the provided vehicle capacity is higher than the demand.

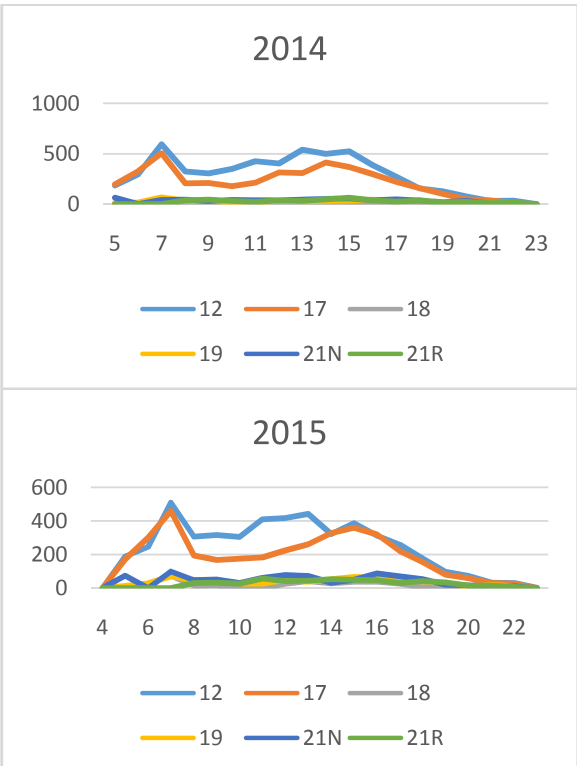


Fig.2 - Passenger flow analysis

CONSUMPTION DATA ANALYSIS: Comparing the 2014 and 2015 annual energy consumption and mileage, we can see that with less energy we can provide even higher frequencies on the main bus lines. This method is presented in the strategies used to improve energy efficiency are.

Table 2 - Passenger flow, distances, fuel unit consumption

2014					
Linia	Calatori	Consum	Distanta	l/100km	l/calator
12	5532	494.8417	1297.15	38.1483791	0.08945078
17	4121	386.1655	991.5	38.9476046	0.09370675
18	126	44.611	119.4	37.3626466	0.35405556
19	470	74.28	204	36.4117647	0.15804255
21N	633	97.74	279.4	34.9821045	0.15440758
21R	482	85.808	245.3	34.9808398	0.1780249

2015					
Linia	Calatori	Consum	Distanta	l/100km	l/calator
12	4824	501.0005	1374.9	36.4390501	0.10385583
17	3712	357.9819	951.9	37.6070911	0.09643909
18	335	19.6073	118.4	16.5602196	0.05852925
19	690	34.9637	207.4	16.8581003	0.05067203
21N	868	44.6579	274	16.2985036	0.05144919
21R	534	42.9508	254	16.9097638	0.08043221

STRAGEGY TO INCREASE ENERGY EFFICIENCY: Based on analyzes, the questionsare:How can we improve energy-efficiency in public transport to reduce costs? How can public transport become more attractive, "passenger friendly"? Can we improve our provided services and gain a higher profit at the same time? Which public transport systems are more energy-efficient, more economical? Which systems should be a priority, should be developed? [5].

After deeply analysis of passenger flows and correlation with delivered transport capacity, the local public transport company decided in 2014 to optimize the relation between both key performance indicator to achieve small and medium-capacity buses. It was tendered five pieces of KARSAN-Jest, small-capacity bus, with 11 sitting and 10 standing place, and seven piece ISUZU-Novocity, medium-capacity bus which has 16 sitting and 39 standing places. The KARSAN average fuel consumption is 11 liter/100km, while the ISUZU 16 liter/100km. Compared to, a standard capacity SOLO (12m long, cca.100 passenger capacity) bus consumption of between 31 and 35 liter/100km. In addition, procurement has increased with five large capacity (18m long, 150 passenger) articulated buses, of which consumption is between 49 and 55 liter/100km.

Fig.3 - KARSAN JEST, small capacity bus (21 passenger)

Fig.4 - ISUZU Novocity, medium capacity bus (55 passenger)

Fig.5 - SOLARIS Urbino 12, most used capacity bus (107 passenger)

Fig.6 - MAN, high capacity bus (155 passenger)

Analyzing the passenger flow we could estimate the necessary vehicle capacity we should provide for each line in each part of the day. In 2015 we optimized the provided vehicle capacity for demand.

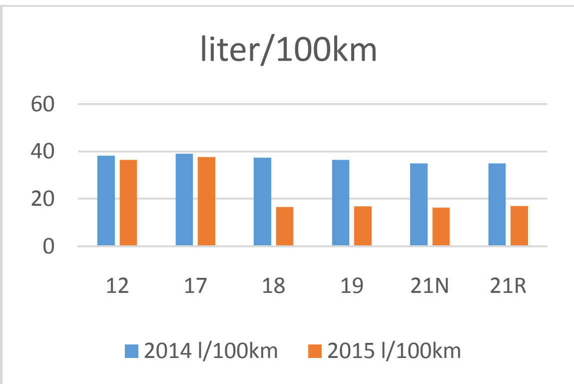


Fig.7 - Average Consumption/Year/Line

As we can see on mainbus lines, such as the line 12 or 17we have achieved savings, despite the fact that on these lines, at rush hours, we used as well the large capacity, articulated buses with high consumption data. However, medium and small capacity buses used in off-peak hours not just compensate the higher fuel consumption, but also in comparison with the 2014 data may be noticed a small decline. On the less frequented lines, as line 18 or 19 we managed to reduce the fuel consumption per kilometer to half compared to 2014 fuel consumption. The delivered vehicle capacity optimization leads not only to energy-efficiency and economic benefits, but also an increase in the comfort level of passengers on main bus lines by usingthe large capacity buses during rush hours.

3. TRAM AND BUS SYSTEM ENERGY-EFFICIENCY COMPARISON

To be able to compare the electricity and liquid fuel consumption data, we need a common denominator. This will be the above-mentioned oil equivalent TOE. The analyzed periodsare:11/10/2014 - 11/16/2014 and 11/09/2015 - 11/15/2015. As the tram network covers the main transport axes, most passengersare using this kind of transport system:

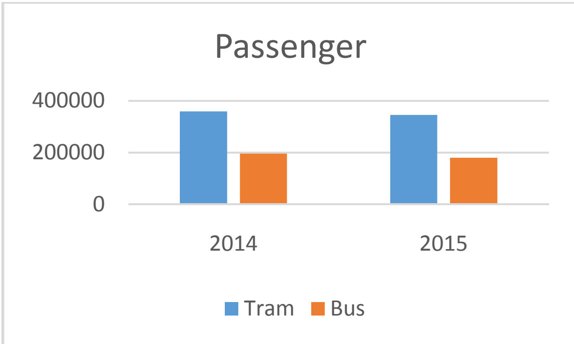


Fig. 8 - Comparison of passenger flow on transport modes

It is evident that in the test period, approximately two-thirds of passengers use the tram and just one-third the bus. Comparing the two public transport system wecan see that the distance traveled is inversely proportional to the number of passengers carried. The mileage data includes data from the metropolitan area lines as well.

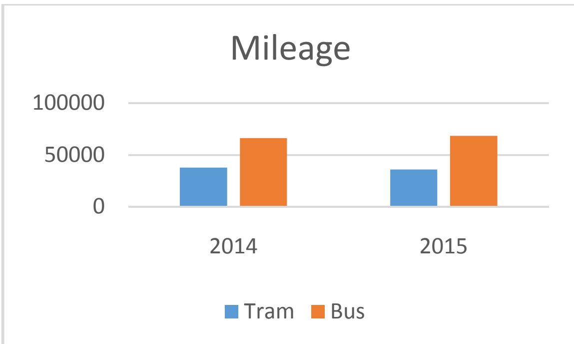


Fig. 9 - Mileage of trams and buses (during this period)

Value (in TOE) of energy consumption for Tram system shows almost half of bus system indicator. The applied strategy (to adapt transport capacity to the real passenger flow) reduced the energy consumption of bus system in 2015.

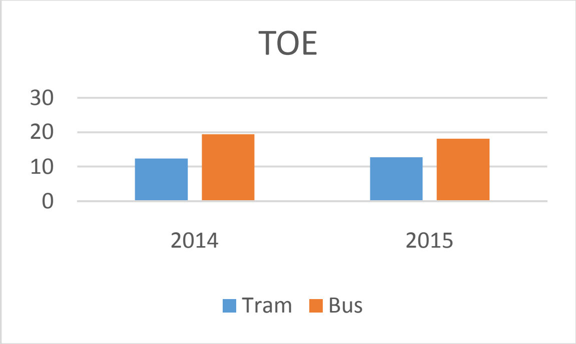


Fig. 10 - Energy consumption calculated in TOE (during this period)

If we compare the energy consumption (in TOE) to the number of passengers carried, the tram systems energy-efficiency is very obvious. Approximately one-third of energy consumption of the bus system. Per ten thousand of passenger in 2014 the tram system used 0.34 TOE of electricity, while the bus system is 0.99TOE, in 2015 energy consumption is similar 0.37 TOE to 1.00 TOE.

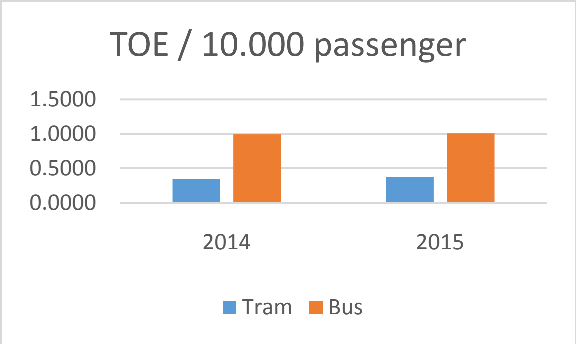


Fig. 11 - Energy Consumption per 10.000 passenger (during this period)

The only examined indicator in which the bus system looks effective than the tram system is the energy consumption per covered distances.

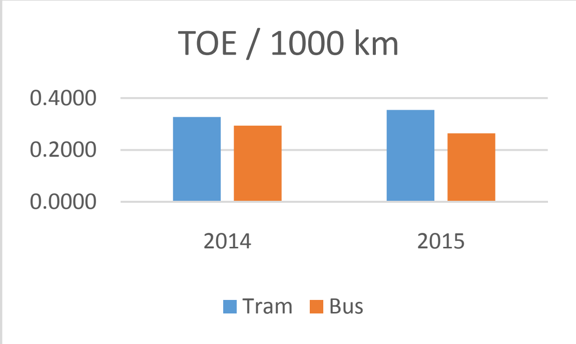


Fig. - Energy consumption for 1.000 km (during this period)

CONCLUSION:

It is important that the mileage of the bus system is approximately twice of the covered distance by the tram system, but the energy consumption percovered distance of the tram system is not significantly higher. Notice that in 2015 the bus system energy consumption indicator is better than in 2014 despite the fact that that the covered distances are increased.

REFERENCES:

[1] I. FELEA, I. CSUZI, E. BARLA: *Modelling and Assessment the Energy Performance of an Urban Transport System with Electric Drives*, Revue Traffic & Transportation “PROMET”, ISSN 0353-5320 UDK 656, Vol.25/2013, p. 495 – 506, Zagreb – Croatia

[2] I. CSUZI: *Contribuţii la evaluarea şi optimizarea performanţelor energetice şi de disponibilitate ale sistemului de tracţiune electrică urbană*, PhD. Thesis – coord. prof.dr.ing. I. FELEA, Univ. Oradea, 2011

[3] I. FELEA, I. CSUZI, E. SILAGHI: *Global indicators used for the availability performance evaluation of an urban transport system using electrically driven trams*, Buletinul AGIR, Bucureşti, 2012, p. 447 – 455

[4] CSUZI I.: *Hogyan működik a nagyváradi közösségi közlekedés – elektronikus flotta menedzsment és kártyás jegyrendszer*, “T-SYSTEMS TEMATIK 2015” Magyarországi Közösségi Közlekedési Konferencia, Balatonfüred, 2015, Szeptember 24-25,

[5] I. FELEA, I. CSUZI, C. SECUI, E. BARLA: *Optimal dimensioning of public urban company tram parks*, “Journal of Sustainable Energy”, ISSN 2067-5534, University of Oradea Editing House, 2015, Vol. VI, No.1, pp.6-11