# Operation Economy of Public Transport Bus Service

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***Abstract:*** *This paper focuses on energy intensity of bus transport vehicles. It aims at reviewing of selected energy parameters in public bus transport, at measurement of fuel consumption when operated by two different bus drivers on the same line, and finally at comparing fuel consumption by both drivers in particular months. A survey of fuel consumption in public bus transport lasted one year, and the results were recorded continuously. The paper comprises of the assessment of fuel consumption by both drivers as recorded in bus log books, followed by the comparison of fuel consumption. We can allege that the driver A drove for more days, travelled more kilometres, and saved more fuel than the driver B.*

***Keywords:*** *bus; fuel consumption; energy requirements; comparison*

## INTRODUCTION

The effort to reduce the fuel consumption of road vehicles must always be based on a specific knowledge of all factors that affect the fuel consumption. This applies to owners of private cars who try to ride with the lowest possible fuel consumption of their personal cars as well as to companies that operate cars, trucks or buses, because the fuel economy of vehicles is an important factor in overall economic performance for them. The opportunity to influence the consumption of fuel for private vehicle owners and companies is different. Ensuring the economical operation of cars does affect not only their fuel consumption but also other important factors such as the amount of exhaust gases emission, reliability, technical readiness of cars, etc. There is a huge group of factors that affect the fuel consumption. Several factors affect the fuel consumption directly and we can evaluate their impact (such as technical parameters of vehicle type and design), while other affect indirectly and we cannot precisely define the extent of their influence. Individual factors affecting the fuel consumption are influencing each other, meaning that they have reciprocal links. The whole issue of fuel consumption should be understood systematically together with solution approach. If attention is paid to one specific area only, another will be neglected, so we can never achieve economical operation. The poor driving technique of driver characterized by a hard and penetrative way of driving will be reflected within a short time on the technical condition of the car. Conversely, the best driver can never ride economically with the vehicle in poor technical condition (Chrastina et al. 2013, 2014). The driver is affecting the fuel consumption by driving technique and overall care of the vehicle, which is an integral part of the driver at work. Correct driving technique requires not only practical experience but also the knowledge of the design of selected type of motor vehicle. The technique of driving at diesel engines may negatively affect the fuel consumption by 20–25 % (Szabó et al. 2013a,b). The degree of actual influence of driving techniques on fuel economy is directly related to operating conditions and circumstances. The influence degree of driving technique is higher under challenging operating conditions and, conversely, is lower under simple operating conditions. The attainable speed and smoothness of driving are affected by route properties and traffic flow characteristics that affect the fuel consumption as well. Optimal driving conditions can be achieved by construction of quality communications, which positively affect the overall fuel economy of vehicles. Particularly the quality of traffic management can generate significant savings in urban traffic. It is important to remove various barriers that obstruct the traffic fluency. The interaction between the impact of transport route and driving technique of driver is very important in terms of economy (Janoško and Semetko 1998; Janoško et al. 2013, 2014b; Janoško and Chrastina 2014a).

## MATERIAL AND METHODS

The aim of this work was to assess the impact of drivers on the operational economy of bus transport vehicles. The impact of drivers on operational economy was determined for a bus Irisbus Iveco Crossway (Fig. 1) used for the suburban transport of periodic line Nitra – Šaľa, belonging to Veolia Transport Nitra, a.s. Its selected technical parameters are shown in Table1.

**Selected technical parameters of Irisbus Iveco Crossway 12M vehicle**

**Fig. 1** Irisbus Iveco Crossway bus

*Table 1. Selected parameters of the vehicle (Iveco Czech Republic, a.s. 2008)*

| **Irisbus Iveco Crossway 12M** | |
|---|---|
| **Dimensions** | |
| Length | 11 995 mm |
| Width | 2 550 mm |
| Height (without air conditioning) | 3 395 mm |
| Wheelbase | 6 200 mm |
| Height of floor | 860 mm |
| Total weight | 18 000 kg |
| **Engine** | |
| Engine displacement | 5.8 l |
| Number of cylinders | 6 |
| Power | 220 kW (300 bhp) |
| Torque | 1 050 Nm |
| **Gearbox** | |
| Type | Manual six-speed |
| **Wheels and tyres** | |
| Tyres | 295/80 R 22.5 |
| Wheels | 8.25" × 22.5" |
| **Brakes** | |
| Type | Disk brakes |
| | ABS |
| | ASR |
| **Fuel tank** | |
| Volume | 210 l |

### Route of bus transport

Two drivers rotated at regular intervals on the mentioned bus line. According to the timetable, the total distance between cities is 30 km. The bus is travelling through the following sections: Nitra, bus station; Cabaj – Čápor; Močenok; Šaľa railway station (Fig. 2).

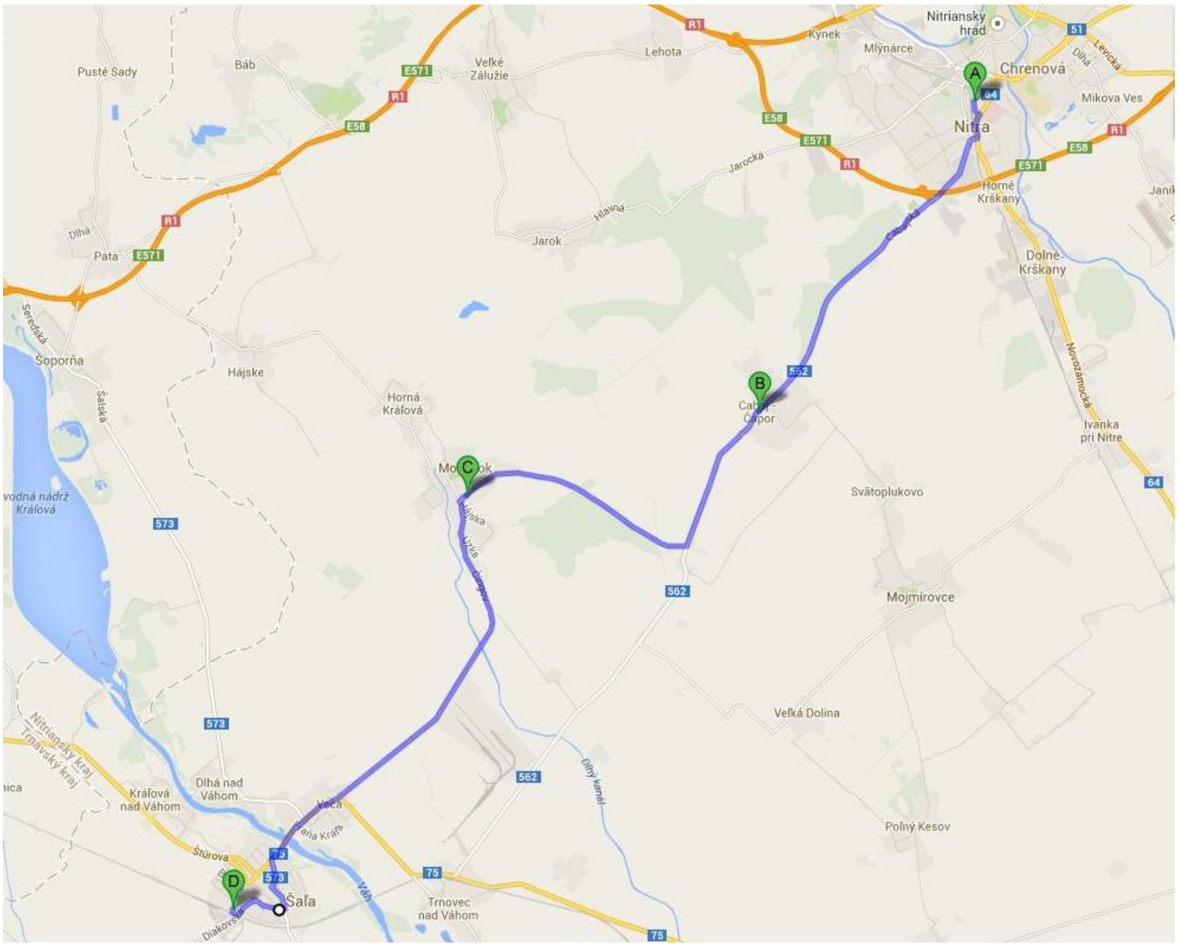


**Fig. 2** Route of bus transport

Marked points on the map:

A) Nitra, bus station;
B) Cabaj – Čápor;
C) Močenok;
D) Šaľa, railway station.

**Impact of driver on operational economy of vehicle**

The examination of the impact of driver on operational economy of vehicle focused on the average fuel consumption of individual drivers while driving for 100 km and consequently on total fuel consumption. The amount of consumed fuel was detected by a simple method based on refuelling into the vehicle tank at the end of each working day of driver. The fuel consumption report showed how many litres of fuel were refuelled at the gas station to vehicle. This method is based on the amount of gas pumped into the main tank of vehicle (l) during the monitored period and also on the number of kilometres travelled by the vehicle (km) during the monitored period.

Fuel consumption was calculated according to Eq. (1):

$$S_{p1} = \frac{V}{L} 100 \qquad (1)$$

where: $S_{p1}$ – fuel consumption (l/100 km);
$V$ – amount of refuelled diesel (l);
$L$ – distance travelled by the vehicle (km).

Because in the winter months it is necessary to heat the vehicle while air temperatures are different for each day, the impact of driver on the operational economy of vehicle calculated according to selected equation for fuel consumption would be distorted due to fuel consumption for heating the vehicle. Because the drivers cannot determine the amount of fuel consumed for heating and heating of the vehicle per day, differences in fuel consumption could occurred, affecting the final fuel consumption of drivers as well as driver's impact on the operational economy of public transport vehicle. Therefore, the amount of fuel consumption was calculated according to Eq. (2), which excludes differences in fuel consumption between drivers caused by the consumption of fuel for heating and heating of the vehicle. The amount of fuel consumption per ride could be calculated according Eq. (2):

$$S_{p2} = \frac{V - V_{vo}}{L} 100 \qquad (2)$$

where: $S_{p2}$ – fuel consumption on a ride (l/100 km);
$V$ – volume of refuelled diesel (l);
$V_{vo}$ – volume of diesel consumed for heating of the vehicle (l);
$L$ – distance travelled by the vehicle (km).

The amount of fuel calculated according to Eq. (2) was compared with the amount of fuel recorded by the flow meter Adast Js6 8500.06 (Fig. 3).

A simplified relationship can be used to calculate the fuel consumption by using the flow meter:

$$S_{p100} = \frac{m_p \cdot P_e}{3 \cdot 6 \cdot 10^4 \cdot \rho_p \cdot v} \qquad (3)$$

where: $S_{p100}$ – fuel consumption for 100 km (l/100 km);
$m_p$ – specific consumption of engine (g/kW·h);
$P_e$ – efficient engine performance (kW);
$\rho_p$ – specific weight of fuel (kg·dm$^3$); v – vehicle speed (km/h).

Specific consumption of engine can be determined from the RPM curve. This fuel consumption indicator was involved in the fuel delivery system of the bus. The flow meter Adast was calibrated in advance, and the values were measured during calibration, as can be seen in Table 2.

**Fig. 3** Flow meter Adast Js6 8500.06

*Table 2. Measured and calculated values during calibration of the flow meter Adast*

| Number of measurements | Time (s) | Pump speed ($min^{-1}$) | Delivery of fuel | Volume of fuel in measuring cylinder(ml) | Total volume of fuel – flow meter ($dm^3$) | Difference between measuring cylinder and flow meter (%) | Total volume of fuel – PC ($dm^3$) | Difference between flow meter and PC ($dm^3$) | Calculated flow rate - measuring cylinder ($dm^3$/h) | Calculated flow rate – PC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 300 | 702 | min. | 175 | 0.175 | 0.000 | 0.176 | 0.001 | 2.1 | 2.16 |
| 2 | 300 | 702 | min. | 175 | 0.175 | 0.000 | 0.174 | −0.001 | 2.1 | 2.16 |
| 3 | 300 | 702 | min. | 180 | 0.175 | 2.857 | 0.176 | 0.001 | 2.16 | 2.16 |
| 4 | 300 | 702 | min. | 180 | 0.175 | 2.857 | 0.174 | −0.001 | 2.16 | 2.16 |
| 5 | 300 | 702 | min. | 176.5 | 0.174 | 1.437 | 0.174 | 0 | 2.12 | 2.16 |
| **Average** | **300** | **702** | | **177.3** | **0.175** | **1.43** | **0.1748** | **0** | **2.13** | **2.16** |
| **Max. value** | | | | | | **2.86** | **0.176** | **0.001** | | |
| **Dispersion** | | | | | | **2.04** | | **0** | | |
| **Standard deviation** | | | | | | **1.43** | | **0.001** | | |
| 6 | 90 | 702 | max. | 225 | 0.228 | −1.316 | 0.231 | −0.003 | 9 | 9.36 |
| 7 | 90 | 702 | max. | 225 | 0.227 | −0.881 | 0.233 | 0 | 9 | 9.36 |
| 8 | 90 | 702 | max. | 225 | 0.226 | −0.442 | 0.229 | 0.003 | 9 | 9.36 |
| 9 | 90 | 702 | max. | 225 | 0.228 | −1.316 | 0.231 | 0.003 | 9 | 9.36 |
| 10 | 90 | 702 | max. | 225 | 0.229 | −1.747 | 0.228 | −0.001 | 9 | 9.36 |
| **Average** | **90** | **702** | | **225** | **0.228** | **−1.14** | **0.2304** | **0** | **9** | **9.36** |
| **Max. value** | | | | | | **−1.75** | **0.229** | **0.006** | | |
| **Dispersion** | | | | | | **0.25** | | **0** | | |
| **Standard deviation** | | | | | | **0.5** | | **0.002** | | |

The difference between measured values according to Eq. (2) and the flow meter Adast was approximately 2 %. However, this imprecision meets the 3 % tolerance declared by the manufacturer.

**Work evidence of driver A and driver B**

Differences between the driving modes of the drivers were determined. The base for data processing consisted of the work evidence of the drivers in the form of recording sheets, determining the actual fuel consumption. The data obtained were processed by a quantitative method and verified by a qualitative analysis.

Subsequently, the recording sheets for the drivers were created, consisting of data on total kilometres, bus drivers, average fuel consumption per 100 km, and total fuel consumption. The sheets were created for each driver for the period December 2011 – November 2012. The data obtained were progressively recorded on these sheets by the person responsible. The survey lasted for one year, and the values measured with both drivers were mutually compared.

## RESULTS AND DISCUSSION

Data recorded after each working day were filled in the record sheets corresponding to each month throughout the year. They are shown in the recording sheets as achievements of the bus driver A and of the bus driver B. Since the survey was conducted during the period December 2011 – November 2012, 12 record sheets were completed. November 2012 was chosen as an example from 12 recording sheets listed in the survey, see Table 3.

The resulting values of the 12 recording sheets were written into the final table, consisting of the monitored parameters of the driver A and of the driver B on a monthly basis during the period December 2011 – November 2012, see Table 4.

*Table 3. Monitored parameters of the drivers in November 2012*

| | **Number of working days in the month** | **Travelled kilometres** | **Norm l/100 km** | **Premium to the norm (%)** | **Total fuel consumption according to norm (l)** | **Total fuel consumption (l) – real** | **Heating and warming-up (l)** | **Difference between standardized and real fuel consumption (l)** | **Average fuel consumption (l/100 km)** | **Total fuel consumption without heating and warming-up (l)** | **Fuel consumption per ride (l/100 km)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Driver A** | 1 | 322 | 24 | 0 | 79.5 | 72 | 2.2 | 7.5 | 22.36 | 69.8 | 21.68 |
| | 2 | 302 | 24 | 0 | 72.5 | 71 | 0 | 1.5 | 23.51 | 71 | 23.51 |
| | 3 | 322 | 24 | 0 | 77.3 | 74 | 0 | 3.3 | 22.98 | 74 | 22.98 |
| | 4 | 242 | 24 | 0 | 60.6 | 61 | 2.5 | −0.4 | 25.21 | 58.5 | 24.17 |
| | 5 | 322 | 24 | 0 | 77.3 | 75 | 0 | 2.3 | 23.29 | 75 | 23.29 |
| | 6 | 302 | 24 | 4.8 | 77.9 | 78 | 2 | −0.1 | 25.83 | 76 | 25.17 |
| | 7 | 302 | 24 | 4.6 | 78.3 | 78 | 2.5 | 0.3 | 25.83 | 75.5 | 25 |
| | 8 | 302 | 24 | 5.5 | 76.5 | 75 | 0 | 1.5 | 24.83 | 75 | 24.83 |
| | 9 | 322 | 24 | 1 | 80.6 | 80 | 2.5 | 0.6 | 24.84 | 77.5 | 24.07 |
| | 10 | 302 | 24 | 0 | 74.8 | 75 | 2.4 | −0.2 | 24.83 | 72.6 | 24.04 |
| | 11 | 302 | 24 | 0 | 74.7 | 71 | 2.2 | 3.7 | 23.51 | 68.8 | 22.78 |
| | 12 | 302 | 24 | −0.1 | 74.7 | 70 | 2.3 | 4.7 | 23.18 | 67.7 | 22.42 |
| | 13 | 302 | 24 | 0 | 74 | 74 | 1.5 | 0 | 24.5 | 72.5 | 24.01 |
| | 14 | 328 | 24 | 0 | 78.7 | 78 | 0 | 0.7 | 23.78 | 78 | 23.78 |
| | 15 | 322 | 24 | 0 | 79.8 | 80 | 2.5 | −0.2 | 24.84 | 77.5 | 24.07 |
| | **Total** | **4 596** | | | **1 137.2** | **1 112** | **22.6** | **25.2** | **24.22** | **1 089.4** | **23.72** |
| **Driver B** | 1 | 302 | 24 | −0.1 | 74.7 | 75 | 2.3 | −0.3 | 24.83 | 72.7 | 24.07 |
| | 2 | 268 | 24 | 0 | 64.3 | 64.1 | 0 | 0.2 | 23.92 | 64.1 | 23.92 |
| | 3 | 302 | 24 | 0 | 73 | 73 | 0.5 | 0 | 24.17 | 72.5 | 24.01 |
| | 4 | 328 | 24 | 6.7 | 86.5 | 87 | 2.5 | −0.5 | 26.52 | 84.5 | 25.76 |
| | 5 | 302 | 24 | 0 | 75 | 75 | 2.5 | 0 | 24.83 | 72.5 | 24.01 |
| | 6 | 322 | 24 | 0 | 77.3 | 77 | 0 | 0.3 | 23.91 | 77 | 23.91 |
| | 7 | 242 | 24 | 0 | 58.1 | 52 | 0 | 6.1 | 21.49 | 52 | 21.49 |
| | 8 | 302 | 24 | 0 | 72.5 | 72 | 0 | 0.5 | 23.84 | 72 | 23.84 |
| | 9 | 322 | 24 | 0 | 77.3 | 76 | 0 | 1.3 | 23.6 | 76 | 23.6 |
| | 10 | 302 | 24 | 0 | 72.5 | 72 | 0 | 0.5 | 23.84 | 72 | 23.84 |
| | 11 | 302 | 24 | 0 | 72.5 | 71 | 0 | 1.5 | 23.51 | 71 | 23.51 |
| | 12 | 302 | 24 | 0 | 72.5 | 71 | 0 | 1.5 | 23.51 | 71 | 23.51 |
| | **Total** | **3 596** | | | **876.2** | **865.1** | **7.8** | **11.1** | **24** | **857.3** | **23.79** |

Table 3 shows that the driver A worked 15 days and travelled 4 596 km in November 2012. Total fuel consumption was 1 112 l within 15 days. According to norm, 1 137.2 l should be consumed within 15 days, thus 25.2 l of fuel were saved. The driver B worked 12 days and travelled 3 596 km in November 2012, while fuel consumption was 865.1 l. According to norm, 876.2 l should be consumed within 12 days, thus 11.1 l of fuel were saved.

*Table 4. Final table of monitored parameters from December 2011 to November 2012*

| | **Month** | **Total number of travelled kilometres** | **Total fuel consumption according to norm (l)** | **Total fuel consumption (l) – real** | **Heating and warming-up (l)** | **Difference between standardized and real fuel consumption (l)** | **Average fuel consumption (l/100 km)** | **Total fuel consumption without heating and warming-up (l)** | **Average fuel consumption per ride (l/100 km)** |
|---|---|---|---|---|---|---|---|---|---|
| **Driver A** | 12/11 | 4 319 | 1 068.2 | 1 055 | 25.5 | 13.2 | 24.31 | 1 029.5 | 23.75 |
| | 1/12 | 4 526 | 1 167.4 | 1 139.6 | 14 | 27.8 | 25.25 | 1 125.6 | 24.89 |
| | 2/12 | 3 764 | 982.3 | 944 | 41.5 | 38.3 | 25.17 | 902.5 | 24 |
| | 3/12 | 4 052 | 1 002.8 | 965 | 29.4 | 37.8 | 23.83 | 935.6 | 23.09 |
| | 4/12 | 4 361 | 1 046.9 | 975 | 0 | 71.9 | 22.38 | 975 | 22.38 |
| | 5/12 | 4 454 | 1 069.1 | 990 | 0 | 79.1 | 22.23 | 990 | 22.25 |
| | 6/12 | 4 656 | 1 117.7 | 1 021 | 0 | 96.7 | 21.95 | 1 021 | 21.95 |
| | 7/12 | 4 254 | 1 021.2 | 901 | 0 | 120.2 | 21.22 | 901 | 21.22 |
| | 8/12 | 4 114 | 987.6 | 888 | 0 | 99.6 | 21.61 | 888 | 21.61 |
| | 9/12 | 4 661 | 1 118.8 | 1 061.3 | 0 | 57.5 | 22.76 | 1 061.3 | 22.76 |
| | 10/12 | 4 462 | 1 079.5 | 1 036 | 8.5 | 43.5 | 23.22 | 1 027.5 | 23.03 |
| | 11/12 | 4 596 | 1 137.2 | 1 112 | 22.6 | 25.2 | 24.22 | 1 089.4 | 23.72 |
| | **Total** | **52 219.00** | **12 798.70** | **12 087.90** | **141.50** | **710.80** | **23.18** | **11 946.40** | **22.89** |
| **Driver B** | 12/11 | 3 837 | 943.9 | 943 | 15 | 0.9 | 24.6 | 928 | 24.21 |
| | 1/12 | 3 601 | 929.1 | 922.1 | 12.5 | 7 | 25.63 | 909.6 | 25.29 |
| | 2/12 | 4 012 | 1 053.3 | 998 | 42.3 | 55.3 | 24.85 | 955.7 | 23.82 |
| | 3/12 | 4 180 | 1 029.8 | 1 001.5 | 26.2 | 28.3 | 23.97 | 975.3 | 23.34 |
| | 4/12 | 3 992 | 958.3 | 924.4 | 0 | 33.9 | 23.1 | 924.4 | 23.1 |
| | 5/12 | 3 676 | 882.4 | 854.9 | 0 | 27.5 | 23.26 | 854.9 | 23.26 |
| | 6/12 | 3 924 | 941.9 | 878.6 | 0 | 63.3 | 22.36 | 878.6 | 22.36 |
| | 7/12 | 4 718 | 1 132.6 | 1 048.1 | 0 | 84.5 | 22.22 | 1 048.1 | 22.22 |
| | 8/12 | 3 569 | 850.2 | 779 | 0 | 71.2 | 21.83 | 779 | 21.83 |
| | 9/12 | 3 471 | 833 | 802.1 | 0 | 30.9 | 23.12 | 802.1 | 23.12 |
| | 10/12 | 4 400 | 1 060.6 | 1 022 | 4.4 | 38.6 | 23.22 | 1 017.6 | 23.12 |
| | 11/12 | 3 596 | 876.2 | 865.1 | 7.8 | 11.1 | 24 | 857.3 | 23.79 |
| | **Total** | **46 976.00** | **11 491.30** | **11 038.80** | **108.20** | **452.50** | **23.51** | **10 930.60** | **23.29** |

Recording sheets indicated that the driver A drove for 179 days and the driver B for 157 days during the monitored period. They travelled 99 195 km together and 23 126.7 l of fuel were consumed, while 24 290 l supposed to be consumed according to company's assumption. The driver A travelled 52 219 km, which represents 52.6 % of the total number of travelled kilometres, and the driver B travelled 46 976 km, which represents 47.4 % of the total number of travelled kilometres. The difference of travelled kilometres between the drivers is 5 243 km. Travelled kilometres per month, recorded for both bus drivers, are presented in Fig. 4.

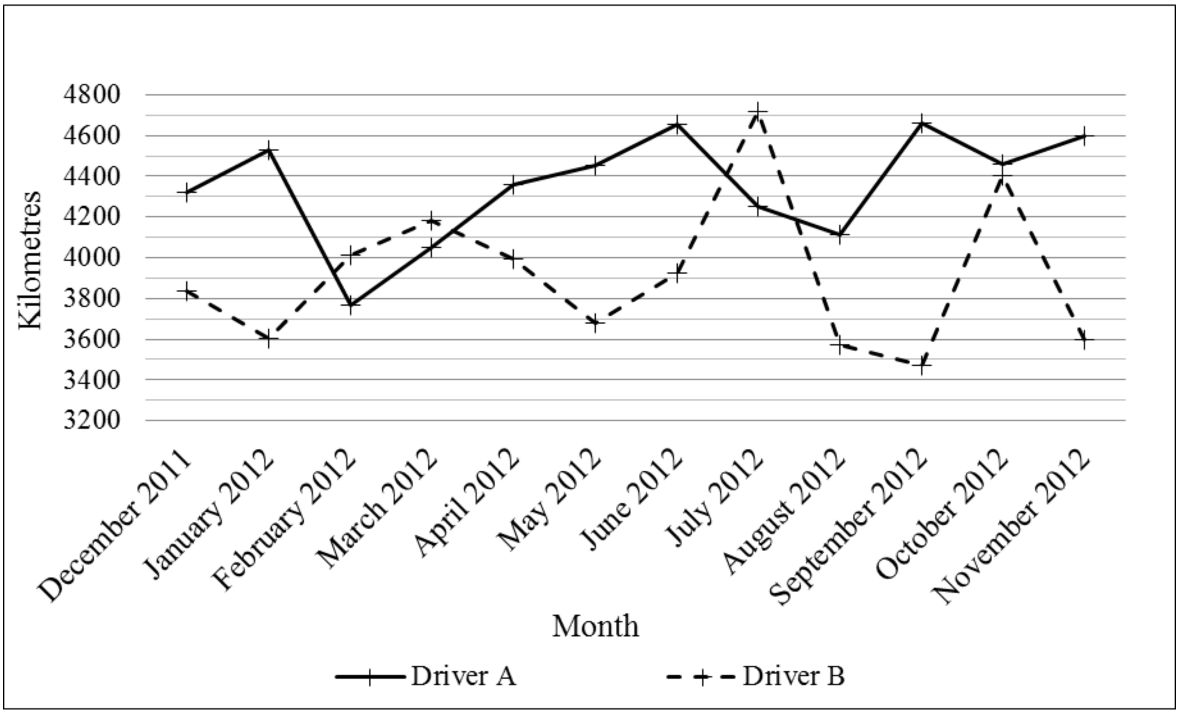


**Fig 4.** Travelled kilometres per month

The driver A supposed to reach 12 798.7 l of fuel consumption per travelled kilometres, representing 52.7 % of the total norm, while his measured fuel consumption was 12 087.9 l, which means that he reached 94.4 % of the total expected fuel consumption. This consumption includes 141.50 l of fuel used for heating and warming-up of the vehicle in the winter months. The difference between consumptions represents a fuel saving of 710.8 l, 5.6 % respectively. Fuel consumption without heating and warming-up was 11 946.4 l, which is fuel consumption determined for driving only. The driver B supposed to reach 11 491.3 l of fuel consumption per travelled kilometres, representing 47.3 % of the total norm. His measured fuel consumption was 11 038.8 l, which means that he reached 96.1 % of the total expected fuel consumption. This consumption includes 108.2 l of fuel used for heating and warming-up of the vehicle. The difference between consumptions represents a fuel saving of 452.5 l, 3.9 % respectively. Fuel consumption without heating and warming-up was 10 930.6 l, which is the fuel consumption determined for driving only. Total fuel consumption per month without heating and warming-up, recorded for both bus drivers, is presented in Fig. 5.

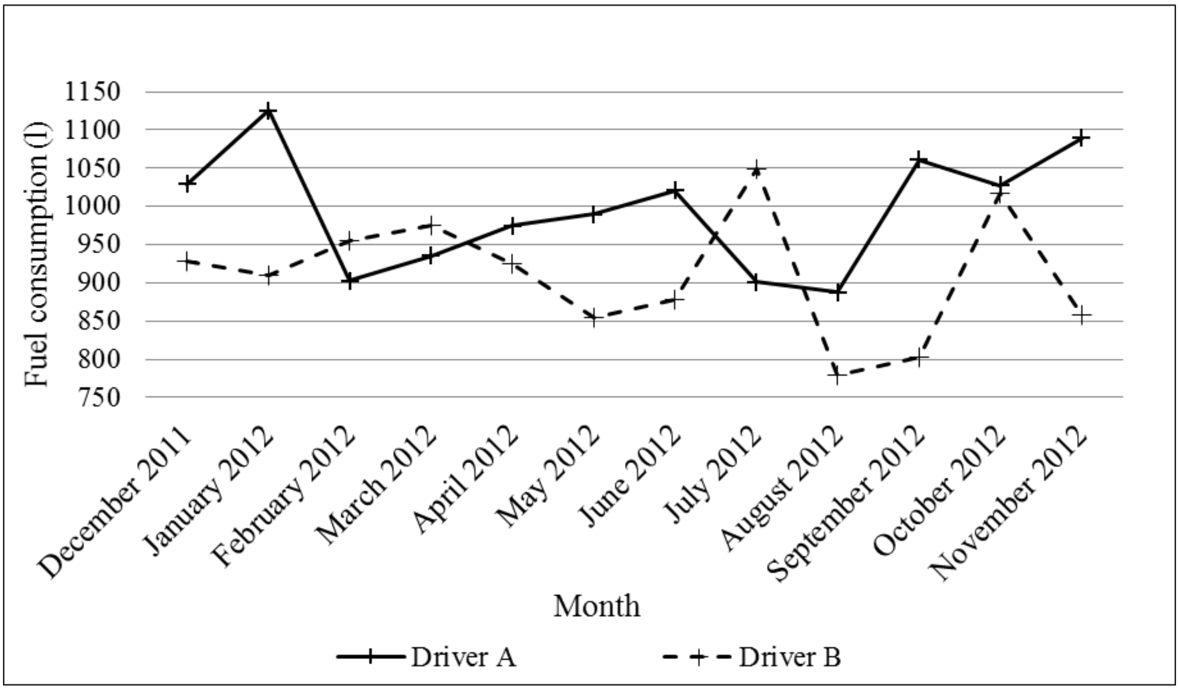


**Fig 5.** Total fuel consumption per month without heating and warming-up

Average fuel consumption in the long-term interval is 23.2 l per 100 km for the driver A and 23.5 l per 100 km for the driver B, while the norm established by the company for the selected type of bus is 24 l per 100 km. Average fuel consumption without heating was 22.9 l per 100 km for the driver A and 23.3 l per 100 km for the driver B. The values of average monthly fuel consumption reached by both bus drivers are presented in Fig. 6.

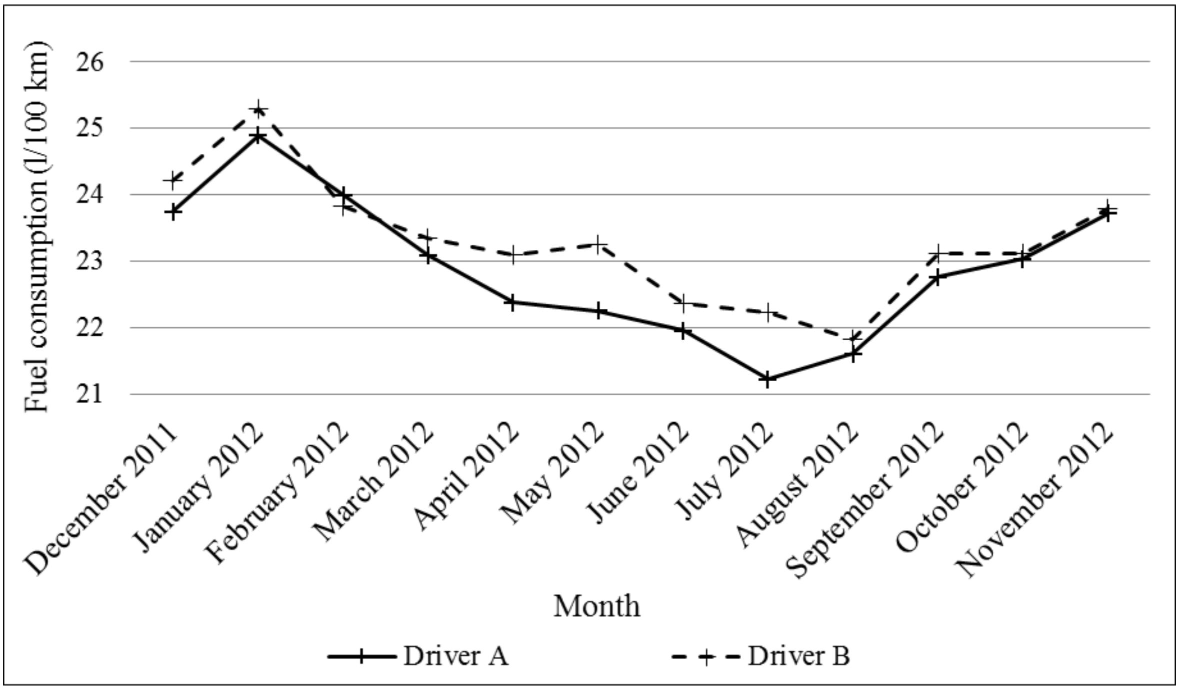


**Fig 6.** Average fuel consumptions per month

Fig. 6 indicates that the driver A reached lower average fuel consumption per 100 km in the long term compared to the driver B. This average fuel consumption is probably influenced by the driving style of both drivers because they rotate on the same bus and the same bus route.

## CONCLUSION

The recording sheets were used to determine the fuel consumption of both bus drivers travelling on the same bus line. The results were processed and subsequently compared. At the end of our experiment, we can allege that the driver A drove for more days, travelled more kilometres, and saved more fuel than the driver B. Both drivers saved up a considerable amount of fuel. The highest average fuel consumption per 100 km was recorded especially in the winter months, because of conditions such as low air temperatures, poor adhesion conditions, larger tire rolling resistance caused by snow on the road, etc. At the same time, during the winter months, it is necessary to heat the vehicle with additional heating due to low thermal efficiency of the diesel engine, resulting in additional fuel consumption. The lowest fuel consumption reached by both drivers was recorded in the summer months because the air temperature was higher. Of course, this may be due to the fact that July and August are the months of summer holidays, so the public transport bus service is not fully overloaded by travellers.

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