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# Speed limits and their impact on emissions production and fuel consumption

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**Abstract.** The article deals with emissions and fuel consumption of road vehicles in real traffic conditions. The aim of this study was to prove or disprove correctness of the decision of Prague city government to change the speed limits from 70 km $h^{-1}$ to 50 km $h^{-1}$ on the parts of one main road leading to/from Prague. For measurements in real traffic conditions was used 2 typical Czech cars Skoda with manual transmission (Fabia 1.2 MPI with petrol engine and Octavia 2.0 TDI with diesel engine). Measurements were performed on both of directions on defined road segment.
At speed 50 km $h^{-1}$ the measurement was repeated 5 times at 3rd and 5 times on 4th gear. Similarly at speed 70 km $h^{-1}$ the measurement was repeated 5 times at the 4th and 5th gear. The aim was to operate the vehicle in the normal engine loads.
The results demonstrate the fundamental assumption that at the higher allowed vehicle speed the engine is more loaded and therefore produces a higher amount of emissions, but according to a higher vehicle speed the emissions are produced on the defined segment for the shorter time. A similar trend is evident even in fuel consumption. The results also indicate the depending on the power reserve of specific vehicle. When the vehicle is more powerful, higher permitted speed is preferable.

**Key words:** speed limit, emission, fuel consumption, on-road measurement, vehicle.

## INTRODUCTION

The increase of road transport (especially the individual transport) is a worldwide problem in the major part of cities. Prague is the capital of the Czech Republic with an area of 496.2 square kilometers and a population of approximately 1.26 millions. The daily traffic volume for year 2014 amounted to 600 thousand vehicles (PTY, 2015).

The increasing traffic intensity brings many negative impacts. The most significant negative impacts of transport include the production of harmful exhaust emissions, noise, vibration, annexation of land for transport infrastructure or traffic accidents (Vojtisek-Lom et al., 2009; Vojtisek-Lom et al., 2015).

Vehicle manufacturers are required to comply with increasingly stringent emission limits for new vehicles, but there is a significant difference between the emissions produced during the homologation and in real traffic. (Vojtisek-Lom et al., 2009; Weiss et al., 2012) Methodology prescribes testing vehicles on a chassis dynamometer under laboratory conditions. The purpose of the chassis dynamometer is mainly reproducibility and comparability of results. According to current methodologies are set limits for the CO, $CO_2$, HC, $NO_X$, PM a PN (CD 1999/100/EC).

Another attempt to reduce direct $CO_2$ emissions is the use of biofuels. They reduce the direct dependence on fossil fuel reserves, increase utilization of agricultural land and support the treatment of bio–waste. Different fuels based on vegetable oils, FAME, fats, HVO and others can be used for diesel engines (Pexa et al., 2015; Vojtisek-Lom et al., 2015). In the case of spark ignition engines are used alcohol fuels on methanol, ethanol or butanol basis (Hromádko et al., 2009; Mařík et al., 2014; Kotek et al., 2015; Sayin & Balki, 2015).

A whole range of other factors are disruptive to vehicle in real traffic, which directly cause the negative effects of vehicles on the environment. Crucial influence has a driver behavior and his driving style, which can lead to fold increase in emissions and fuel consumption during an inefficient aggressive driving (De Vlieger, 1997; T.-Q. Tang et al., 2015). Another influencing factor is the type of road that defines the speed limit, number and arrangement of lanes, crossing with other roads or the occurrence of other road users (cyclists and pedestrians). These impacts can be partially eliminate by the operational management of traffic using intelligence traffic systems (ITS) that can regulate the traffic based on the current traffic situation (Grant-Muller & Usher, 2014).

Often neglected negative impact is traffic noise. It is reported that the noise causes a range of physical and mental diseases. The often solution of this problem is a decrease in a speed limits, the choice of a suitable road surface and structural measures in the form of noise barriers (Foraster et al., 2011).

Named unfavorable noise pollution was the main reason for the design of traffic–engineering solutions on a road that connects the city of Prague and the D1 motorway. After reducing the maximum speed of 70 to 50 km $h^{-1}$ surface treatment road has been a slight reduction in noise pollution (1–2 dB). The aim of this experiment was to evaluate the above traffic measures in terms of emissions and fuel consumption of the representatives of the two most commonly used vehicle (Skoda Octavia 2.0 TDI and the Skoda Fabia 1.2 HTP) on a defined segment in both directions at a constant speed of 50 km $h^{-1}$ and 70 km $h^{-1}$.

## MATERIALS AND METHODS

For the experiment were used two most common vehicles in the Czech Republic. As a representative of a small–volume vehicle with a petrol engine was voted the Skoda Fabia 1.2 HTP and as a medium class car with a turbocharged diesel engine was chosen Škoda Octavia 2.0 TDI. Detailed parameters of both vehicles are shown in Table 1.

For emission measurement was used emission analyzer VMK, specially designed for mobile measurement. It is a 5–components emission analyzer, whose technical data are summarized in Table 2.

During the measurement was recorded vehicle operating data from the engine control unit via the OBD interface (engine speed, load, speed, MAF, IAT, fuel consumption). For communication and record data from the OBD was used car diagnostic system VAG–COM.

**Table 1.** Technical parameters of measured vehicles

| Vehicle | Octavia 2.0 TDI | FABIA 1.2 HTP |
|---|---|---|
| | COMBUSTION ENGINE | |
| Design | compression ignition, turbo charged | spark ignition, atmospheric |
| Number of cylinders and valves | 4, in row, 16 valves | 3 in row, 6 valves |
| Fuel | Diesel | gasoline |
| Volume of cylinders | 1,968 ccm | 1,198 ccm |
| Power | 103 kW at 4,000 rpm | 40 kW at 4,750 rpm |
| Torque | 320 Nm at 1,750 rpm | 106 Nm at 3,000 rpm |
| EU limit | EU4 | EU4 |
| | CAR BODY | |
| Service weight | 1,395 kg | 1,055 kg |
| Total weight | 1,995 kg | 1,570 kg |
| | DRIVE PERFORMANCE | |
| Max. speed | 208 km $h^{-1}$ | 150 km $h^{-1}$ |
| Acceleration 0–100 km $h^{-1}$ | 9.6 s | 18.5 s |
| Fuel consumption | 7.0 / 4.7 / 5.5 (liter per 100 km) | 7.8 / 4.8 / 5.9 (liter per 100 km) |
| Manufacture year | 2005 | 2002 |
| Mileage | 45,000 km | 80,000 km |

**Table 2.** Technical parameters of mobile emission analyser

| Measured values | Measurement range | Resolution | Accuracy |
|---|---|---|---|
| CO | 0...10% Vol. | 0.001% Vol. | 0…0.67%: 0.02% absolute, 0.67%…10%: 3% of measured value |
| $CO_2$ | 0...16% Vol. | 0.01% Vol. | 0…10%: 0.3% absolute, 10…16%: 3% m.v. |
| HC | 0...20,000 ppm | 1 ppm | 10 ppm or 5% m.v. |
| $NO_X$ | 0...5,000 ppm | 1 ppm | 0…1,000 ppm: 25 ppm, 1,000…4,000 ppm: 4% m.v. |
| $O_2$ | 0...22% Vol. | 0.1% Vol. | 0…3%: 0,1% 3…21%: 3% |

The fuel consumption of the car Skoda Fabia was evaluated by a flow meter WF007 fitted to the fuel system of the car. The technical parameters of the flowmeter shown in Table 3.

**Table 3.** Technical parameters of flow–meter WF007

| Parameter | Value |
|---|---|
| Measuring principle | Oval gear |
| Sensing principle | Hall Sensor |
| Flow range | 0.005–1.5 l $min^{-1}$ |
| Pulses output | 1,800 pulses $l^{-1}$ |
| Viscosity | 0–2,000 mPas |
| Accuracy | ±0.5% |

For check compliance with the prescribed speed and position sensing vehicle was used GPS system DEWETRON VGPS 200C.

General overview of the used measuring devices is illustrated in Fig. 1.

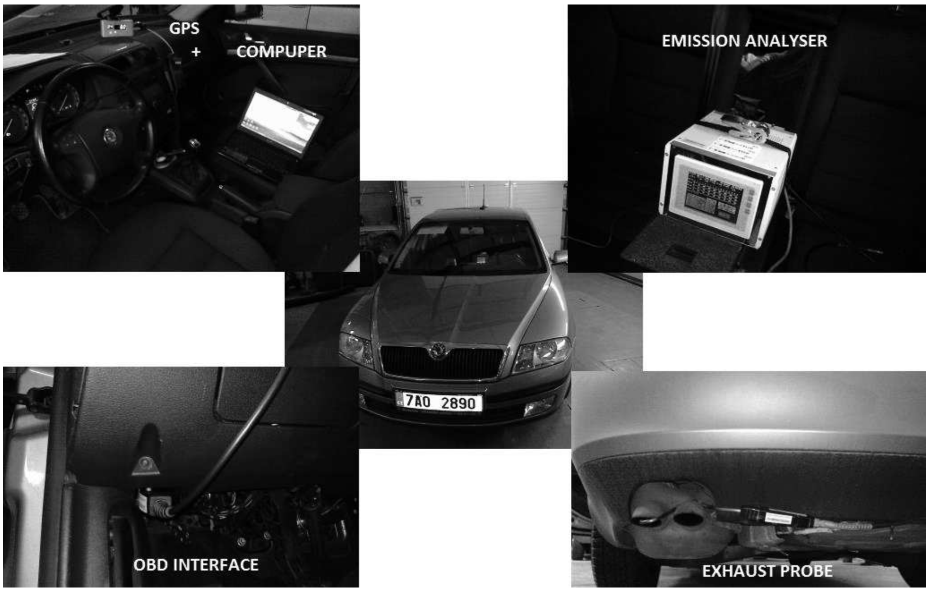


**Figure 1.** Equipment of measuring vehicle.

The measurement was carried out on the predetermined part of road (see. Fig. 2), which relates to the mentioned speed limits. The road has three traffic lanes in each direction and connects Prague and Brno the second largest city in the Czech Republic.


**Figure 2.** Map of measured track.

Road's horizontal alignment is shown in Fig. 3

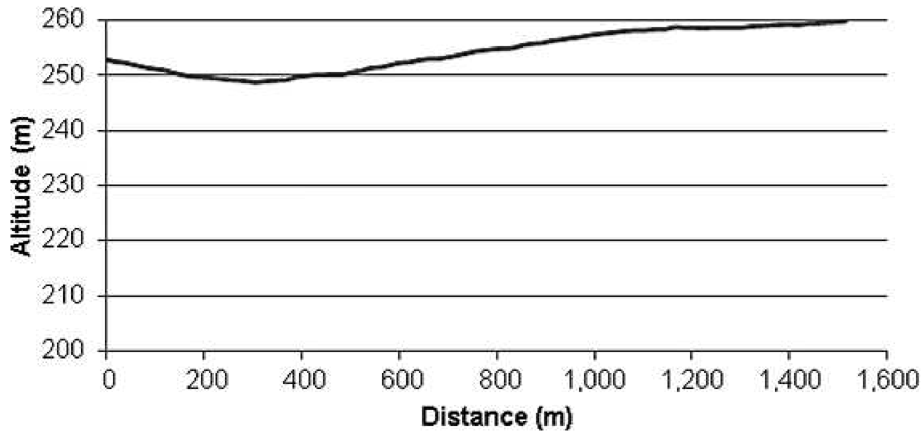


**Figure 3.** Road's horizontal alignment (direction to the city centre).

There is a direct relation between engine load, engine speed and emissions produced, as is clear from the introduction to this article. Engine load cause overcoming driving resistances. In this case, the driving resistances mainly influenced by a preset vehicle speed, other parameters have remained constant or at most similar. To limit the influence of the engine speed was important to choose the right gear for the specific vehicle speed. Generally, the higher the engine speed, the higher the vehicle will produce emissions. During the experiment was considered a 'reasonable driver behaviour', thus for the mentioned speed limits were selected always 2 different gear grades corresponding to the optimal revolutions range for each engine of the vehicle. For speed of 50 km $h^{-1}$ were chosen gear 3 and 4, for the speed of 70 km $h^{-1}$ were chosen gear 4 and 5. For each speed and direction of travel the measurements were repeated 5 times for each gear grade.

Measurements were performed during the night hours to eliminate the effects of ambient traffic. During the measurement was temperature about 5 °C and constant weather conditions, random wind effect was minimized by repeating the measurement. First was performed all drives at the constant speed of 50 km $h^{-1}$ on 3th gear grade for both direction. Then these drives were repeated on the 4th gear. Next measurement was performed at the constant speed of 70 km $h^{-1}$ on 4th gear grade for both direction and then on 5th gear.

## RESULTS AND DISCUSSION

Fig. 4 is an example of instantaneous values of CO, $CO_2$, $NO_x$, HC, fuel consumption and engine speed with Skoda Fabia when driving in the direction of the city center at speeds of 50 and 70 km $h^{-1}$. The figure shows that at a higher speed all monitored values increased. It is further apparent that at higher vehicle speeds the engine is operated at slightly higher revolutions.

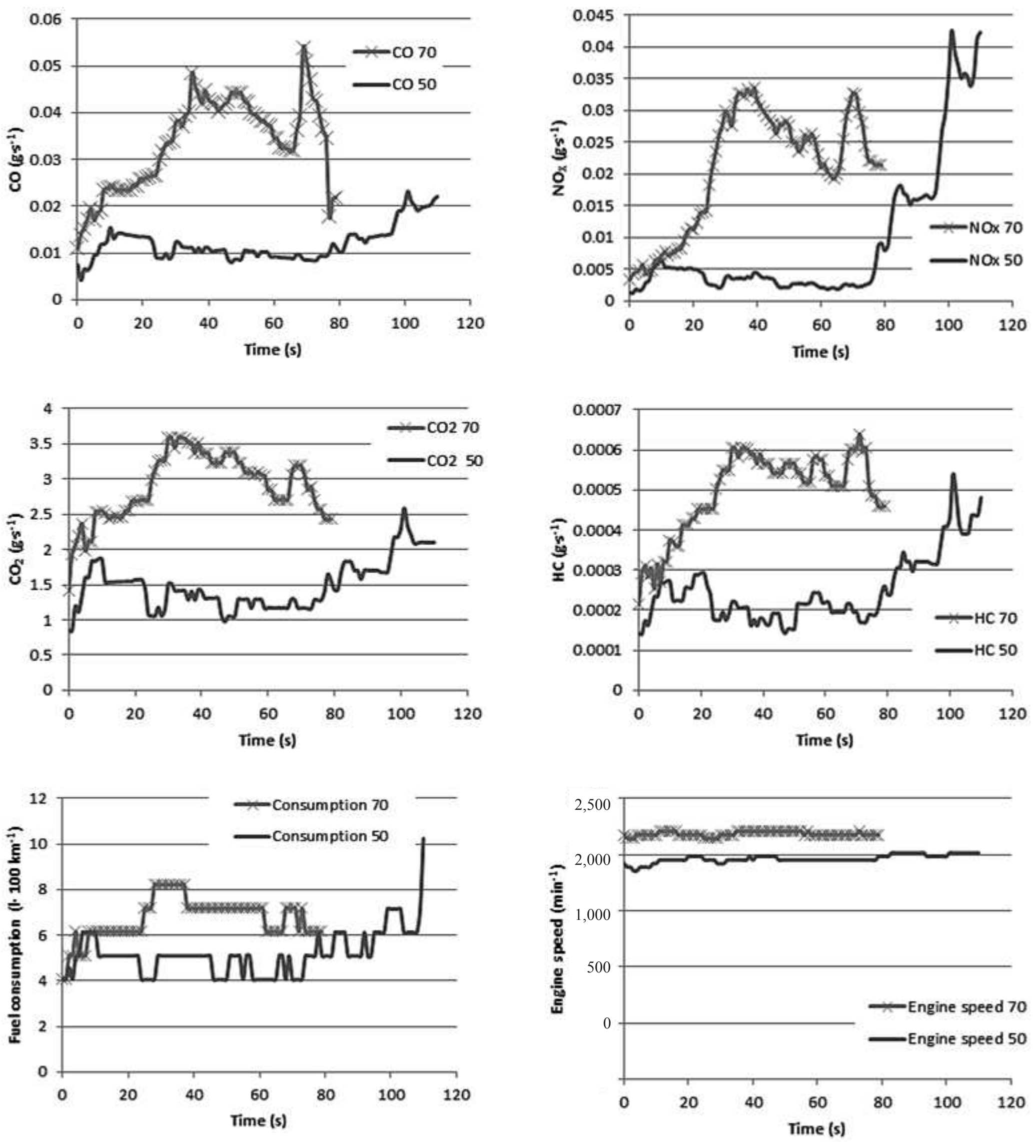


**Figure 4.** Instantaneous values of emissions, fuel consumption and engine speed with Skoda Fabia, direction from town.

A very similar situation can be seen in Fig. 5 driving Škoda Octavia towards the center at both monitored speeds. There is not shown the concentration of CO, because during operation in both cases was measured zero production. Even here the engine was operated at a slightly higher speed at a speed of 70 km $h^{-1}$.

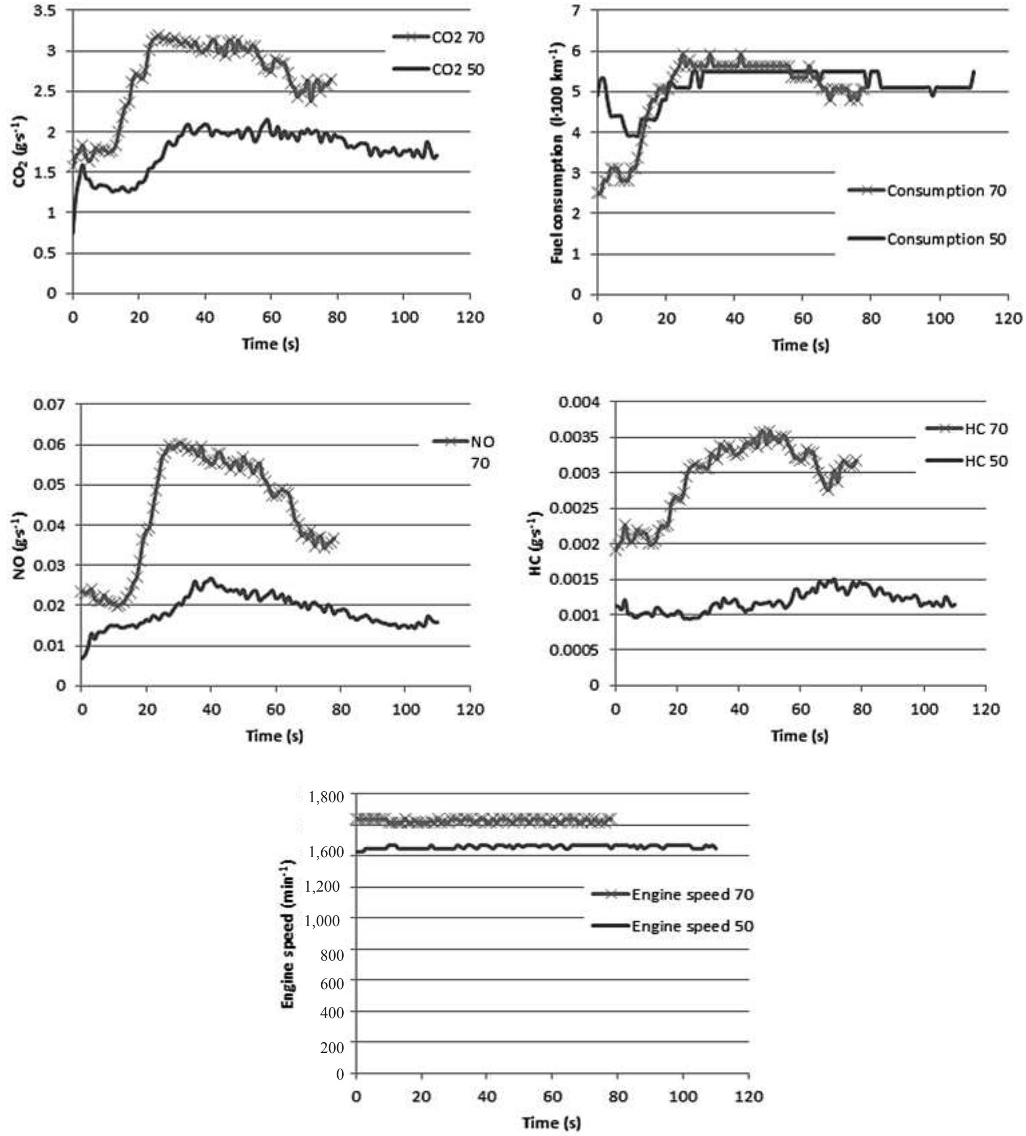


**Figure 5.** Instantaneous values of emissions, fuel consumption and engine speed with Skoda Octavia, direction to town.

At higher speeds there are always higher instantaneous emissions at higher engine speeds, but for a shorter period, as shown in Figs 4 and 5.

The following Table 4–7 summarizes the average values of the engine operating parameters, the total production of emissions and fuel consumption for each vehicle in both directions. For the more transparency of results data were averaged for both predefined gear grades.

**Table 4.** Summary results of measured values for Skoda Octavia, direction from centre town

| | total time | avg. engine speed | avg. engine load | avg. speed (OBD) | CO | $CO_2$ | $NO_X$ | HC | avg. speed (GPS) | fuel consump-tion |
|---|---|---|---|---|---|---|---|---|---|---|
| | s | $min^{-1}$ | Nm | $km\ h^{-1}$ | g | g | g | g | $km\ h^{-1}$ | l |
| | 109 | 1,739 | 63 | 51.3 | 0.00 | 183 | 3.26 | 0.1900 | 50.6 | 0.071 |
| | 78 | 1,850 | 77 | 71.4 | 0.00 | 181 | 2.00 | 0.1857 | 70.4 | 0.063 |
| difference | -31 | 112 | 13 | 20.2 | 0.00 | -1 | -1.26 | -0.0043 | 19.7 | -0.007 |

**Table 5.** Summary results of measured values for Skoda Octavia, direction to centre town

| | total time | avg. engine speed | avg. engine load | avg. speed (OBD) | CO | $CO_2$ | $NO_X$ | HC | avg. speed (GPS) | fuel consump-tion |
|---|---|---|---|---|---|---|---|---|---|---|
| | s | $min^{-1}$ | Nm | $km\ h^{-1}$ | g | g | g | g | $km\ h^{-1}$ | l |
| | 109 | 1,734 | 78 | 51.1 | 0.00 | 221 | 2.52 | 0.1932 | 50.4 | 0.085 |
| | 78 | 1,844 | 97 | 71.3 | 0.00 | 228 | 2.90 | 0.2217 | 70.1 | 0.082 |
| difference | -31 | 110 | 19 | 20.1 | 0.00 | 7 | 0.38 | 0.0285 | 19.7 | -0.003 |

**Table 6.** Summary results of measured values for Skoda Fabia, direction from centre town

| | total time | avg. engine speed | avg. engine load | avg. speed (OBD) | CO | $CO_2$ | $NO_X$ | HC | avg. speed (GPS) | fuel consump-tion |
|---|---|---|---|---|---|---|---|---|---|---|
| | s | $min^{-1}$ | % | $km\ h^{-1}$ | g | g | g | g | $km\ h^{-1}$ | l |
| | 109 | 2,353 | 25 | 49.3 | 2.11 | 187 | 1.57 | 0.0340 | 50.8 | 0.074 |
| | 78 | 2,480 | 33 | 69.0 | 2.48 | 195 | 2.38 | 0.0295 | 70.7 | 0.074 |
| difference | -31 | 127 | 8 | 19.6 | 0.37 | 8 | 0.81 | -0.0044 | 19.9 | 0.000 |

**Table 7.** Summary results of measured values for Skoda Fabia, direction to centre town

| | total time | avg. engine speed | avg. engine load | avg. speed (OBD) | CO | $CO_2$ | $NO_X$ | HC | avg. speed (GPS) | fuel consump-tion |
|---|---|---|---|---|---|---|---|---|---|---|
| | s | $min^{-1}$ | % | $km\ h^{-1}$ | g | g | g | g | $km\ h^{-1}$ | l |
| | 109 | 2,337 | 28 | 49.1 | 2.22 | 206.62 | 1.42 | 0.0359 | 50.6 | 0.082 |
| | 78 | 2,454 | 39 | 68.3 | 2.86 | 229.14 | 2.50 | 0.0346 | 70.1 | 0.086 |
| difference | -30 | 117 | 11 | 19.2 | 0.64 | 23 | 1.08 | -0.0013 | 19.5 | 0.004 |

Increasing the vehicle speed of both vehicles has resulted in increased engine load, as shown in Table 4–7. A higher engine load was achieved in both cases in the direction of the city center. Yet in the case of Škoda Octavia due to shorter driving time there is a negligible increase in emissions and a decrease in fuel consumption at higher speeds. For Skoda Fabia were worse all mentioned parameters excluding HC emissions.

## CONCLUSIONS

Limiting the maximum speed from the perspective of the drivers is very unpopular. On the other hand, it is necessary to carry out such traffic measures that will have a positive impact on the environment.

Reducing the maximum speed in this case had a negligible effect on the noise production. Therefore, measurements were taken other negative impacts of transport on the environment in the form of measuring emissions and fuel consumption of two vehicles on a defined road. Unfortunately, even these results are not substantial argument for maintaining or increasing the maximum permitted speed. Differences in emissions production are too low that more importance will be the driver's behavior and instantaneous traffic situation than adhering to speed limits. It cannot be said that lower speed limit is some major limitations of drivers. Time savings is only 30 seconds, however most drivers are very irritated by this restriction. Perhaps that is why finally maximum speed was increased again to 70 km $h^{-1}$ effect from January 1, 2016.

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