COMPARISON OF GROUND AND UNDERGROUND ROUTES BY ANALYSING OPERATING PARAMETERS OF DRIVEN VEHICLE

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Abstract. The article deals with an impact evaluation of the newly opened Prague tunnel complex (called "Blanka") and it is focused on passenger car time savings and exhaust emission production (floating car data - FCD). The tunnel complex connects two districts of Prague from the west to the northeast. The driving distance, from origin to destination (OD), was 6.4 km. Two different routes were proposed for OD. The first route was led on surface roads, the second one led through the new tunnel complex. All drives were carried out during the afternoon rush hours and were conducted in both directions. The way of driving was affected only by the immediate and surrounding traffic situation and the driver respected all traffic regulations. The FCD were recorded with the support of OBD, e.g., the engine speed, engine load, MAF, velocity etc. during all drives. The PEMS emission analyser VMK for measuring and recording the instantaneous values of exhaust emissions (CO, CO_2, NO_X, HC, O_2) with integrated GPS system was installed in the vehicle to determine the position of the car and the velocity as well. The results prove that there were significant time savings and emission decreases on the tunnel complex drives. The offer of the new underground route split traffic flows and it causes a significant release on the original surface routes. Nevertheless, it still possible to find many disadvantages of the surface routes as many intersections (even without traffic lights), pedestrian crossings and sharing the traffic space with public transport (trams, buses) etc. These obstacles cause significantly longer duration of drives; increase the idle time and more frequent car acceleration, i.e. increase of the exhaust emissions and fuel consumption.

Keywords: traffic, emissions, combustion engine, operating parameters.

Introduction

The increase of road transport (especially the passenger car transport) becomes a worldwide problem in major parts of all cities. A rapid growth and expansion of urban centres and suburban areas increase the traffic demand that exceeds the road capacities in most cities and it is a major cause for occurrence of frequent congestions. The increasing traffic intensities bring many negative impacts. The most significant ones include (beyond prolonging of the driving time) higher production of harmful exhaust emissions, noise, vibration, agricultural land-take used for transport infrastructure or traffic accidents [1; 2].

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 tests and under real traffic conditions [2]. Vehicles should be tested, in compliance with the methodology, on a chassis dynamometer under laboratory conditions. The purpose of these measurements is mainly reproducibility and comparability of the results. There are set up limits for CO, CO_2, HC, NO_X, PM and PN according to the current methodologies [3].

A whole range of other factors influences a vehicle under real traffic conditions and it directly causes negative effects of vehicles on the environment. The driver's behaviour and his driving style lave crucial influence that can generate emissions and fuel consumption during an inefficient or aggressive way of driving [4; 5]. Another influencing factor is the type of the road that defines the speed limit, number and arrangement of lanes, intersections with other roads or occurrence of other road users (cyclists and pedestrians). These impacts can be partially eliminated by operational management of the traffic using intelligence traffic systems (ITS) that can regulate the traffic based on the current traffic situation [6].

The very often neglected negative impact is the traffic noise. It is reported that noise causes a range of physical and mental diseases. Often the solution of this problem is the decrease in the speed limits, the choice of a suitable road surface and structural measures in the form of noise barriers or shift of the traffic into tunnels [7].

The aim of the planned experiments was to compare the newly opened Prague tunnel complex (called "Blanka") and to find the time savings/losses and real exhaust emission production of the driven passenger car in comparison with the classic surface route. Prague is the capital city of the

Czech Republic, with an area of 496.2 square kilometres and population of app. 1.26 million. The daily traffic volume for the year 2014 amounted to 600 thousand vehicles [8].

Materials and methods

Volkswagen Golf V. generation was used for this experiment. Detailed technical specification is summarized in Table 1.

Table 1

Vehicle technical specification

Vehicle	VOLKSWAGEN GOLF V
Combustion engine	
Design	spark ignition, atmospheric
Number of cylinders and valves	4 in row, 16 valves
Fuel	gasoline
Volume of cylinders	1390 ccm
Power	59 kW at 5000 rpm
Torque	132 Nm at 3800 rpm
CO_2 emission	164 $g \cdot km^{-1}$
EU limit	EU4
Car body	
Service weight	1153 kg
Total weight	1770 kg
Drive performance	
Max. speed	168 $km \cdot h^{-1}$
Acceleration (0-100 $km \cdot h^{-1}$)	13.9 s
Fuel consumption	9.4 / 5.5 / 6.9 litre/100 km

A mobile on-board emission analyser VMK was used to measure the emissions. The analyser uses the non-dispersive infrared (NDIR) method to detect CO, CO_2, and HC emissions and electrochemical cell to O_2 and NO_X emissions. Data were recorded with 1 Hz frequency on memory card. The analyser was equipped with the GPS system Garmin GPS-18x-5Hz to record the position and speed of the vehicle. The technical data of the analyser are summarized in Table 2.

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 … 1000 ppm: 25 ppm, 1000 … 4000 ppm: 4 % m.v.
O_2	0 ... 22 % Vol.	0.1 % Vol.	0 … 3 %: 0.1 %, 3 … 21 %: 3 %

During the measurements the vehicle operating data were recorded from the engine control unit via the OBD interface (engine speed, engine load, speed, MAF, IAT). Cad diagnostic system VAG-COM was used for communication and recording the data from the OBD. The general overview of the used measuring devices is shown in Fig. 1.

The experimental drives were conducted during weekdays at the time of afternoon rush hours on 12 November 2015. The method Floating car data (FCD) was used in the experiment. It means that the driver kept calm driving style and the drive is influenced by the immediate traffic situation. The origin of the experimental drives was located at P+R parking lot Dejvická. As the destination the parking lot near the exit of the tunnel Blanka was chosen. At first drives in the tunnel complex in both directions were carried out and then surface drives were carried in the experiment.

Fig. 1. **Equipment of measuring vehicle**

The following figures show the route of the tunnel complex Blanka (Fig. 2) and the surface route alongside the tunnel (Fig. 3).

Fig. 2. **Track 1 through the Blanka tunnel complex:** (dashed line marks the tunnel)

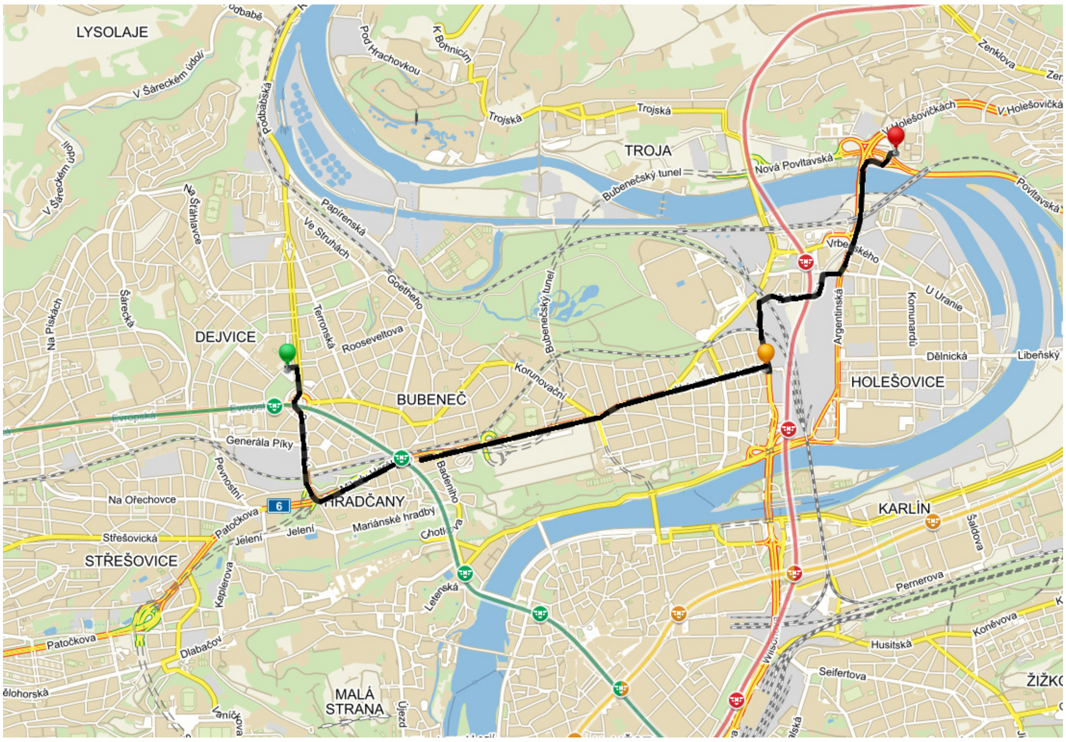

Fig. 3. **Track 2 through ground routes**

Results and discussion

Table 3 summarizes the basic parameters of drives. The results show that when the drives were carried out through the tunnel approximately 50 % time savings were achieved in comparison with the drives on the surface route. This corresponds to the almost double average speed, when the average engine load was kept on almost the same level.

Table 3

Summary results of each route

Track	Length, m	Total time, s	Avg. speed, $km \cdot h^{-1}$	Avg. engine load, %	Time savings, %
Direction 1 – tunnel	5751	664	30	32	44
Direction 1 – surface	5670	1196	16	31	
Direction 2 – tunnel	5640	525	38	36	50
Direction 2 – surface	5677	1048	20	33	

The following Figure 3 shows the time distribution of the various driving modes. It is evident that the drive on the surface routes achieves significant increase in the engine inefficient idling and full load. This is primarily due to the ruggedness of surface transport and necessary frequent stops at intersections or crosswalks and subsequent acceleration. Similar results of time distribution were obtained in [9].

Table 4 summarizes the routes in terms of emissions. It is evident that during smooth-flowing drive in the tunnel there was a significant reduction of all monitored emissions.

It is evident that drives on the surface roads were more affected by the congested traffic conditions. The result shows 23-67 % emission savings in case of the tunnel route. These results confirm other studies concluding that the urban route brings the highest CO emission and fuel consumption due to significant idling and low-speed operation, and the frequent acceleration and deceleration changes [5]. Similar results show that different road types were investigated in Antwerpen for normal driving behaviour under congested traffic conditions [10].

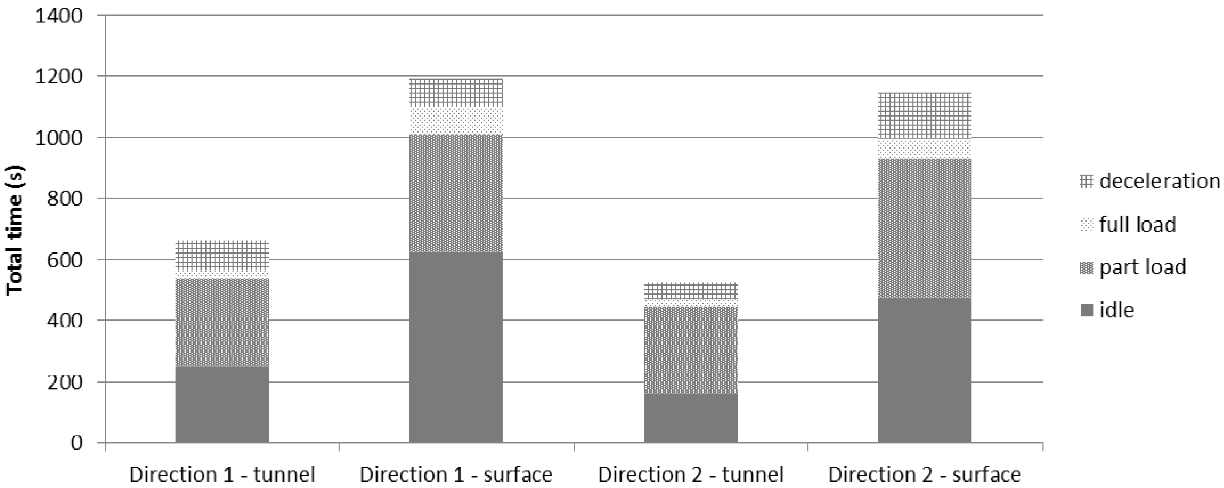

Fig. 3. **Time distribution of the various driving modes**

Table 4

Summary results of emissions on individual routes

Track	CO, g·km^{-1}	CO_2, g·km^{-1}	NO_X, g·km^{-1}	HC, g·km^{-1}	Emissions savings, %			
					CO	CO_2	NO	HC
Direction 1 - tunnel	0.530	140	0.032	0.0098	26	36	67	55
Direction 1 - surface	0.716	219	0.097	0.0218				
Direction 2 - tunnel	0.549	163	0.058	0.0099	23	32	23	27
Direction 2 - surface	0.718	242	0.075	0.0149				

Conclusions

The goal of this study was to assess the impact of vehicular traffic in the Prague tunnel complex "Blanka" and to compare the surface and underground routes from the point of time savings and of exhaust emission production under real traffic conditions. The results proved an assumption about possible reduction of the driving time and also reduction in the quantity of produced emissions on the city ring road (tunnel). In the case of the driving time in the tunnel route approximately 50 % time saving has been reached. A similar situation is evident in the case of emission production, where especially 25 % decrease in CO emission is very important for improving the city environment.

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References

1. Vojtisek-Lom M., Pechout M., Dittrich L., Beranek V., Kotek M., Schwarz J., Vodicka P., Milcova A., Rossnervoa A., Ambroz A., Topinka J. Polycyclic aromatic hydrocarbons (PAH) and their genotoxicity in exhaust emissions from a diesel engine during extended low-load operation on diesel and biodiesel fuels. Atmospheric Environment 109, 2015, pp. 9-18
2. Vojtisek-Lom M., Fenkl M., Dufek M., Mareš J. Off-cycle, real-world emissions of modern light duty diesel vehicles. SAE International. Technical Papers. 2009-24-0148, 2009
3. Commision Directive 1999/100/EC of 15 December 1999 adapting to technicalprogress Council Directive 80/1268/EEC relating to the carbon dioxide emissions and the fuelconsumption of motor vehicles.
4. De Vlieger I. On-board emission and fuel consumption measurement campaign on petrol-driven passenger cars. Atmospheric Environment 31, 1997, pp. 3753-3761.

5. Tang T. Q., Hung W. T., Cheung C.S. Emissions and fuel consumption of a Euro 4 car operating along different routes in Hong Kong. Transportation Research Part D 16, 2011, pp. 415-422
6. Grant-Muller S., Usher M. Intelligent Transport Systems: The propensity for environmental and economic benefits. Technological Forecasting & Social Change 82, 2014, pp. 149-166.
7. Foraster M., Deltell A., Basagaña X., Medina-Ramón M., Aguilera I., Bouso L., Grau M., Phuleria H.C., Rivera M., Slama R., Sunyer J., Targa J., Künzli N. Local determinants of road traffic noise levels versus determinants of air pollution levels in a Mediterranean city. Environmental Research 111., 2011, pp. 177-183.
8. Prague transportation yearbook (PTY) [online] [01.15.2016]. Available at http://www.tsk-praha.cz/wps/portal/root/dopravni-inzenyrstvi/rocenky
9. Frey H.C.H., Unal A., Rouphail N.M., Colyar D.J. On-Road Measurement of Vehicle Tailpipe Emissions Using a Portable Instrument, Journal of the Air & Waste Management Association 53, 2003, pp. 992-1002.
10. De Vlieger I., De Keukeleere D., Kretzschmar J.G. Environmental effects of driving behaviour and congestion related to passenger cars, Atmospheric Environment 34, 2000, pp. 4649-4655.