Evaluation of Passenger Car Emission Indexes in Relation to Passing through the Rail-road Crossing

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Abstract: One of the crucial aspects in the vehicles exhaust emission is, often the long duration of vehicles stop phase before the rail-road crossing before the rail vehicle passes through. During the road vehicle stop, the combustion engine in most cases operates in idling conditions. Some drivers turns off the combustion engines during mentioned stop time. In modern vehicles there is also the start&stop system implemented, which automatically stops and starts the combustion engine. Combustion engine idling phase is related to inefficient operation, where after switching the engine off, the catalytic converter could cool down, which could result in increased emission of harmful exhaust compounds after start of the engine. The analysis made in reference to the Poznan agglomeration, shows many places where alternative routes can be determined with regard to the necessity of reaching the destination, when there is a road-rail crossing on the way. The purpose of the performed work was first of all to determine the potential of reducing fuel consumption and exhaust emission by cars as a result of the improvement in the transport system efficiency. The improvement of transport system efficiency could be assumed as a trip duration reduction, when the driver could receive the information about the actual state of the rail-road infrastructure.

1 INTRODUCTION

The rail-road level crossings are very important part of transport infrastructure. There are well known non-collision rail-road level crossings, which are the best in case of safety and this solution is the most comfortable, because it does not interrupt the road vehicles trip. The non-collision level crossings are much more expensive and need more place, which is crucial in urban locations, that is why most of the existing level crossings consists of railway and road routes placed on the same level. Based on the data from European Railway Agency and The International Union of Railways, there are about 114,000 level crossings in the European Union and 600,000 level crossings in the world. In that case, it is important to ensure enough safety to prevent the accidents. According to a report *Railway Safety Performance in the European Union 2016*, there were 2076 significant accidents in 2014, reported by the EU-28 countries. The traditional level-crossings are a big challenge to ensure enough safety both for train and road vehicle users, and that cases are a subject of scientific papers (Kobaszynska-Twardowska et al, 2018). According to polish law, there are six different categories of rail-road level crossings, described by a letters from A to F. The features of different categories were actualized in the year 2015, assuming among others the new technical specification of trains or infrastructure control systems (Młyńczak, Folega, 2016). Assuming the basic two types of level crossings, much higher level of safety ensure the ones equipped with warning or protection devices, called as active, than the ones described as passive – not equipped with warning or protection devices (Laapotti, 2016). There are many works on improving

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the safety on the rail-road level crossings, which suggest for example use both the Global Navigation Satelite System and optical sensors for train positioning in the railway network (Pelz, 2007). This assumption is favourable, because assumes the use of cheap and reliable technology. There is also another way to improve the safety in case of proper routing of road vehicles.

When the rail-road level crossing is closed, it increases the road congestion, which actually is a big problem, especially in big cities, what was reported by Deloitte and Targeo.pl in a report on traffic jams. In the road congestion conditions, the vehicles fuel consumption increases and also very often the exhaust emission occur very close to the pedestrians. Properly developed rail-road level crossings and surrounding infrastructure improves the efficiency of transport system, which is in accordance with the main objective of sustainable transport system (Ogryzek, Adamska-Kmieć and Klimach, 2020). The Poznan agglomeration develops the public transport system in case of higher frequency of rail journeys, which is another step towards the sustainable transport system and the sustainable development of the city (De Gruyter, Currie and Geoff Rose, 2017).

The authors made before similar, but simulation research only in case of trip duration (Laapotti, 2016). The results were positive in case of longer stop times on rail-road level crossings, which occur very often in polish conditions.

The aim of the authors was to check if makes sense if the driver change the route to avoid standing in road congestion. The considerations were carried out on example of rail-road level crossing, located in Poznan. This location has been selected, because there is an alternative route with collision free rail-road level crossing in the close surroundings. The ecological and economic analysis was carried out and also the travel time was compared in case of the two selected routes. The basis for this consideration were on-road tests of passenger vehicle, performed with PEMS (Portable Emission Measurement System) device. That kind of measurements is very favourable, because it reflects the actual level of exhaust emission on selected road. Such analysis could be performed also for whole city or region, where the number of rail-road level crossings is much greater and there are more alternative routes, but in that case a macro scale model is needed. When whole city will be assumed, there should be an analysis made, which road transport related emission modelling method should be chosen – the consumption-based model, EURO standard based model or the speed dependent model (Zefreh, Torok, 2016)

2 METHODOLOGY

For the purpose of the article, the authors considered the rail-road level crossing located on sw. Michala str. in western part of Poznan. The analysed route started from the intersection of Warszawska and sw. Michala streets and finished on a car park at the end of sw. Michala str. (Figure 1). The selected route is characterized by high traffic density and there is possibility of alternative route selection without rail-road level crossing. The distance of alternative route is about 2.1 km and it is approximately 60% more than the primary route.

Figure 1: Analysed test routes (the primary route is marked with blue colour and the alternative route – grey); prepared with use of www.google.com/maps (16.10.2018).

The tests were performed in real driving conditions and the research object was a passenger vehicle propelled with a turbocharged spark ignition engine, compliant with Euro 6 emission standard (Figure 2). Four different scenarios were analysed:

- passage through the rail-road level crossing without stop (described as sw. Michala I),
- trip through the rail-road level crossing including about 1,5 minute stop phase with started combustion engine (described as sw. Michala II),
- passage through the rail-road level crossing including about 1,5 minute stop phase with

stopped combustion engine (described as sw. Michala III),
- trip through the roundabout Srodka and Zawady str. (described as Roundabout Srodka-Zawady).

The assumed stop time seems to be short in polish conditions, but this was obtained in performed on-road tests.

Figure 2: Test vehicle with measurement equipment.

The exhaust emission measurements were performed with PEMS (Portable Emission Measurement System) device: Semtech-DS, manufactured by Sensors (Figure 3). This device is equipped with gas analysers for specified gas concentrations measurements and collects also signals from exhaust flow meter, GPS, ambient module and the vehicles OBD system. That kind of equipment is nowadays used in additional emission on-road tests in the vehicles homologation procedure. Under special conditions stated in the legislative documents, that test is called RDE. The vehicle's engine during all of the analysed tests was already warmed-up

Figure 3: Exhaust emission measurement device Semtech-DS with auxiliary components.

3 RESEARCH RESULTS

The results of performed tests are shown on Figures 4-9. The vehicle speed profiles vary because of local differences in traffic density and the stops on analysed rail-road level crossing (Figure 4). The distance values of analysed test routes is about 1.3 km in the case of primary route and about 2.1 km (+60%) for alternative route with collision-free rail-road level crossing (Figure 5). The duration of performed drives vary between 132 and 253 seconds and thus the average vehicle speed ranges from 18.4 to 42.6 km/h (Figure 5). The shortest trip duration was recorded during passage of the shorter route with opened rail-road level crossing. Test with use of the longer route result in about 35% greater drive time. The greatest duration time values were recorded when the vehicle was driven through shorter route with closed rail-road level crossing (204 and 253 s). This values show, that selection of the longer route with collision-free rail-road level crossing even by short stop time will result in shorter trip duration.

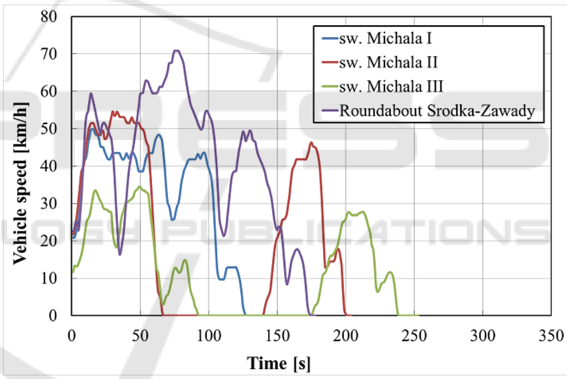

Figure 4: The speed profiles during performed tests.

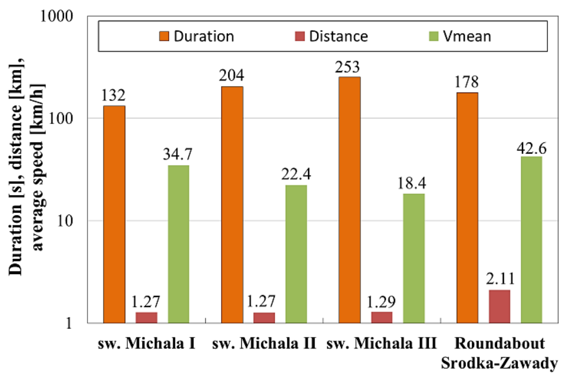

Figure 5: Duration, distance and average speed for different test drives.

As it was revealed, the longer trip distance in analyzed case could result in shorter trip duration. The environmental performance of these passages in terms of gaseous exhaust compounds was also verified (Figures 6-9). The CO_2 emission, which is an effect of fuel consumption, takes the smallest value of approx. 235 g after passing the primary route with opened rail-road level crossing (Figure 6). The greatest CO_2 emission (382.5 g) was recorded after the alternative route passage, which was about 21–24% more than after passing the shorter route with about 1.5 minute stop. Similar dependencies are observed in case of CO emission, but comparing to the shorter route passage, the increase in CO emission after passing the longer distance is 200% (Figure 7). The smallest mass of NO_x was emitted during passing the shorter route with closed rail-road level crossing and the greatest mass of this exhaust compound was emitted during after passing the alternative route (Figure 8). Observed dependencies could arise from different engine operation parameters and thus different in-cylinder temperatures which have influence on NO_x emission. The greatest HC mass was measured after test performed with use of the alternative route (Figure 8).

Obtained emission values were related to the Euro 6 emission standard. All of performed tests in case of CO, NO_x and HC represent much lower emission level than the homologation values. Great influence on such results is that performed tests do not include the cold start of the engine (when the engine coolant temperature is on the level of ambient temperature). The cold start emission will have a great impact to the results, because of the short distance of performed drives compared to the homologation test cycle.

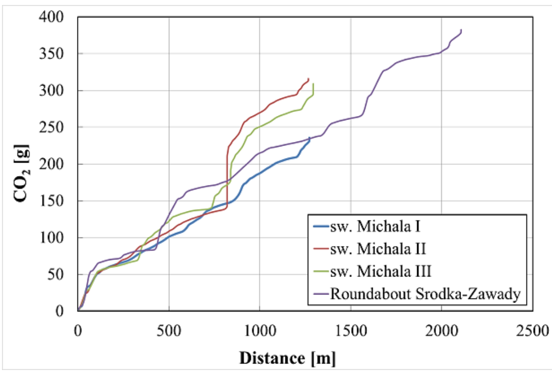

Figure 6: Summarized CO_2 emission obtained during on-road measurements.

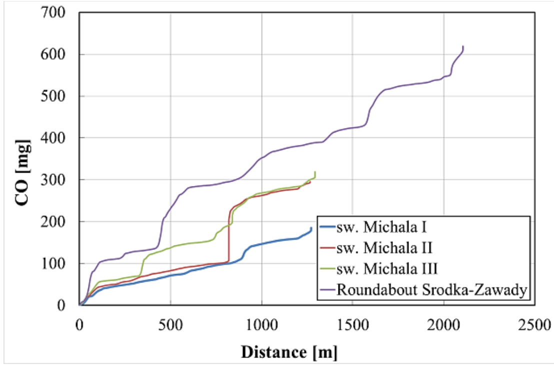

Figure 7: Summarized CO emission obtained during on-road measurements.

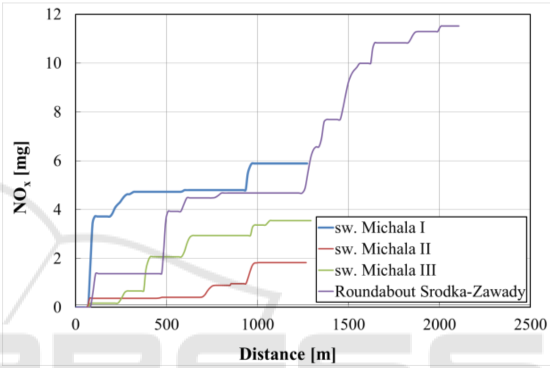

Figure 8: Summarized NO_x emission obtained during on-road measurements.

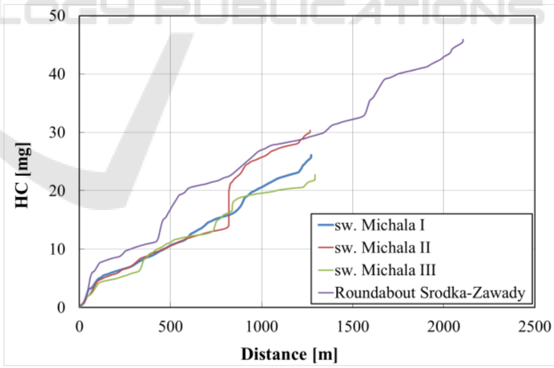

Figure 9: Summarized HC emission obtained during on-road measurements.

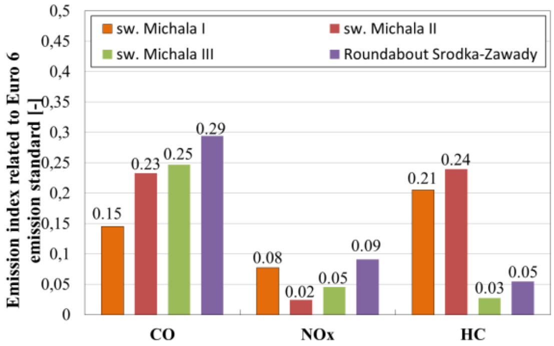

Figure 10: Comparison of emission indexes reflecting the measured emission values related to Euro 6 emission standard.

4 CONCLUSIONS

Performed measurements show the importance of choosing the route both from the point of view of travel time and exhaust emissions. In analysed case, 60% longer distance result in 13–30% shorter travel time, than during drive through shorter route with 1,5 minute stop on closed rail-road level crossing. If only trip duration will be considered, in analysed case, the selection of longer route will benefit in shorter drive time if the stop time will last approx. 1 minute.

The issues related to exhaust emission are more complicated. The emission intensity depend not only from travel time and distance, but also from engine speed and engine load. These very complex rules affect in the greatest mass of emitted exhaust compounds after covering the route characterized by longer distance and higher vehicle speed. Different engine operating conditions – higher load affect in greatest increase (over 2 times) in case of NO_x emission. Probably greater differences could be observed in case of vehicles propelled with compression ignition engines without SCR (Selective Catalytic Reduction) system, which is responsible for NO_x reduction. The disadvantage of using longer route in fuel consumption and CO_2 emission is about 62%. It could be observed, that stop on the rail-road level crossing contributes to systematic increase of CO_2 emission and probably three times longer stop time on closed rail-road level crossing when the engine is switched on, will contribute to such increase of fuel consumption, which will make sense to use the longer route. The performed test drives represent much lower emission values in case of CO, NO_x and HC the Euro 6 homologation values. There is no clear winner in case of the emission indexes. In case of CO, the lowest emission index was obtained during short trip through the opened rail-road level crossing. The most favourable emission index for NOx were obtained during the short trip, when the vehicle was parked on the level crossing with started combustion engine. The HC emission index with the lowest value was obtained during the passage through the rail-road level crossing with stopped combustion engine.

That assumption will have sense, when the car driver will know, that the oncoming rail-road crossing will be closed and should change the route. It should be noted that mostly the stop times are significantly longer than in analysed situation. Deeper insight in that case will give also the research on the influence of using different routes in that areas on ecological and economical indexes from vehicles propelled with compression ignition engines, which are not equipped with three way catalytic converters as test vehicle.

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