A STUDY ON THE USE OF ECO-DRIVING TECHNIQUE IN CITY TRAFFIC

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Abstract

During the operation of vehicles, their operational parameters change, which is related to the influence of working factors, the current situation on the road and its capacity, as well as the wear processes of the vehicle components. Improving the operational and ecological properties of motor vehicles, taking into account technical, legal and operational factors, is a constantly important issue. The article presents selected test results of a vehicle used in the eco-driving technique in urban traffic. The main objective of the study was to verify the possibility of limiting intensive braking and the number of braking thanks to the use of eco-driving. Limitations of intensive braking allow extending the service life of the friction elements of the braking system. The research was carried out on the so-called routine route from work to home in a selected area of the city of Lublin in south-eastern Poland. The obtained research results focus on the influence of selected driving parameters, such as: mileage, road characteristics, number of vehicle stops, number of vehicle stops at intersections and in front of pedestrian crossings, depending on the driving style. The analysis of the results shows the benefits of eco-driving in city traffic.

Keywords: driving style; driving the vehicle; ecology; road traffic

Introduction

The inhabitants of many cities around the world face daily transport problems caused by the increase in the number of vehicles and the limited capacity of the existing road infrastructure. The worst situation is in the centers of large cities and on the main access roads from the increasingly populated suburban areas. Therefore, it is not surprising that many researchers are very interested in the problem of transport congestion [17, 19, 24]. The road network of each city consists of various types of intersections, which enable the handling of collision traffic flows and which can be bottlenecks of the transport system [25]. Because of the narrow streets and density of existing buildings within the city, in most cases it is not possible to extend current infrastructure [18]. The traffic intensity in a given city is not distributed equally throughout the day and over the entire

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area [34]. Many researchers also deal with the problems of the need for vehicles and infrastructure [23, 39] and issues related to traffic control in urban areas [9, 21]. The transport sector is influenced by a wide range of external social and economic factors such as demographics, living standards of the population, urban planning, organization of production, structural changes in society and accessibility to transport infrastructure [46]. Moreover, an important issue is road traffic safety, which is influenced not only by the condition, organization and quality of road infrastructure [2, 26, 43] but also by the technical condition of vehicles [29, 47] and, above all, by the behavior of road users [13, 36, 42].

The transport sector is also responsible for environmental pollution, especially in large agglomerations. Emission of air pollutants from means of transport has a negative impact not only on the environment and human health, but is also recognized as one of the sources influencing climate change [12, 31, 45]. Nocera and Cavallaro [27], demonstrated that the emissions from transport comprise 26% of the total CO_2 emissions in the EU and in this zone are a major factor in air pollution worldwide. Many authors believe that it is possible to reduce vehicle emissions through a variety of technical solutions [15, 20, 22] or the use of alternative fuels [10, 16, 32]. Barkenbus [3], demonstrated that eco-driving is a neglected climate change initiative and following the eco-driving policy may reduce fuel consumption by 10%, which in turn will reduce emissions. The impact of driving technique on reducing fuel consumption and thus lower exhaust emissions was presented in [35, 40, 41]. In the literature we can find many publications in which the authors research impact of the vehicle technical condition [4, 6, 33] and effective driving [9, 37, 44]. The tests of braking power, the number of brakes depending on the elevation profile and the average vehicle speed in suburban traffic are presented in [11] in order to review the potential electricity regeneration capabilities of hybrid electric vehicles. Others, such as Caulfield et al. [8], showed that it is possible to reduce exhaust emissions using an on-board eco-driving feedback tool. Eco-driving means greater concentration and deeper analysis of the road situation, anticipating the manoeuvres of other road users, as well as rational acceleration and skillful braking of the vehicle. Braking is a dynamic effect when the vehicle speed changes over time and on a specific road section [28, 30, 38]. More information on the idea and technique of eco-driving, its benefits and challenges related to the improvement of road traffic are presented in detail by Alam and McNabola [1]. The application of the following principles of eco-driving includes: smooth driving, maintaining moderate engine speed (up to 3500 rpm), limiting the engine idling speed, engine braking, greater concentration of the driver, route selection, anticipation manoeuvres, control of the correct pressure in the vehicle wheels, limiting the use of additional on-board equipment and air conditioning, limiting luggage.

The aim of the study is to present the benefits of driving a passenger car with the use of eco-driving in city traffic with particular emphasis on the number of vehicle stops and the activation of the braking system. The results of research on driving parameters such as: road type, number of vehicle stops and number of braking, number of vehicle stops at intersections and pedestrian crossings for a normal driving style and eco-driving were compared. The road tests were carried out in urban traffic conditions, move in the so-called ”routine route”: work - home in Lublin.

2. Methodology

The tests were carried out at the same specified time of day (around from 2.30 pm to 3 pm), which corresponds to the beginning of the afternoon traffic rush and under comparable traffic conditions, on the same road section – driving from work to home. During the tests, a driver's behavior and various operational activities performed (e.g.: braking, vehicle stops at intersections and other situations) were recorded. The values of individual parameters were manually recorded by the driver in the previously prepared measurement protocol. In order to demonstrate the obtained benefits of eco-driving, the results collected in road tests were analyzed and compared to normal conditions, i.e. those that accompany traveling without economic driving strategies.

The following parameters were taken into account in the research:
- Number of vehicle braking,
- Number of vehicle stops up to 0 km/h,
- Number of vehicle movements,
- Number of stops at traffic lights,
- Number of stops at intersections,
- Number of stops before pedestrian crossing,
- Maximum vehicle speed [km/h],
- Average vehicle speed [km/h],
- Length of the route [km],
- Travel time [min].

The tests were carried out on a 5-door Daewoo Lanos passenger car powered by a 100 HP 1.5 DOHC gasoline engine with power transmission via a 5-speed manual gearbox to the front axle [7]. Production date of the car is 2000, and the vehicle mileage at the start of the tests was 83,560 km. The vehicle has a curb weight of 1020 kg, while the vehicle's weight was around 1150 kg during the tests. In the Table 1, the chosen technical parameters of the engine used in the tested vehicle were presented.

Tab. 1. Chosen technical parameters of the vehicle engine 1.5 DOHC, E-TEC [7]

Parameter		Value
Number and arrangement of cylinders		4-cylinders in line
Work cycle		1-3-4-2
Displacement	[cm^3]	1,498
Compression ratio		9.5
Cylinder diameter	[mm]	76.50
Piston stroke	[mm]	81.50
Total power	[kW/KM]	73/100
at rotational speed	[rpm]	5800
Torque	[Nm]	131
at rotational speed	[rpm]	3400

Tab. 1. Chosen technical parameters of the vehicle engine 1.5 DOHC, E-TEC [7]; cont.

Parameter		Value
Ignition advance angle (for idle speed)	[°]	10
Idle speed	[rpm]	850±50
Cooling system		Forced circulation
Lubrication system		Forced circulation

A routine route from workplace to home was selected for the research. The basic characteristics of this route are shown in Table 2. This road was marked on the map shown in Figure 1. Point A is a beginning of the route – workplace, point F is end of the route – home. The intermediate points (B and E) are larger intersections where the direction of the route has been changed. The route was mapped using the portal [14].

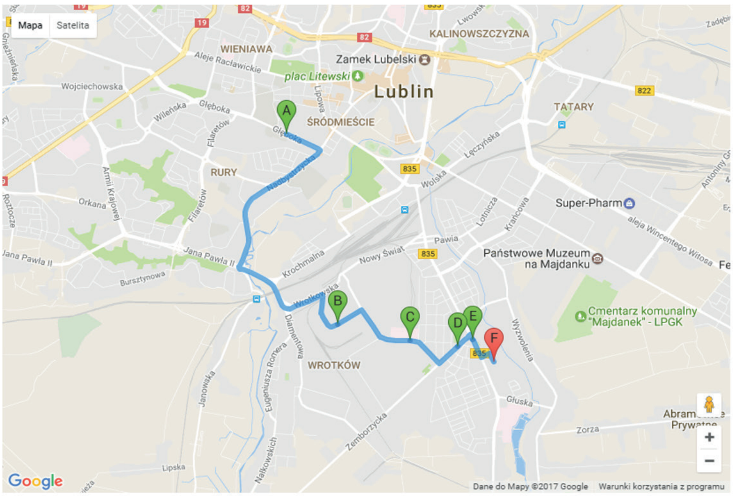

Fig. 1. Marked tested route from work - point A, to home - point F [14]

Tab. 2. Basic data concerning the routing route – from work to home

Route parameters	To home
The length of the travel route [km]	7.7
Number of intersections with traffic lights	7
Number of all pedestrian crossings	34
Number of intersections without traffic lights	11
Number of intersections with railway lines	1

3. Results and discussion

This chapter presents selected results of road tests carried out on the test route from work to home. The focus is on the most important parameters that best illustrate the differences in driving style in the city traffic. The presented test results concern the driving style in normal strategies and with the use of eco-driving, 28 tests were performed. Figure 2 shows the results of tests on the number of brake applications, understood as the number of brake pedal depressions depending on the current road situation.

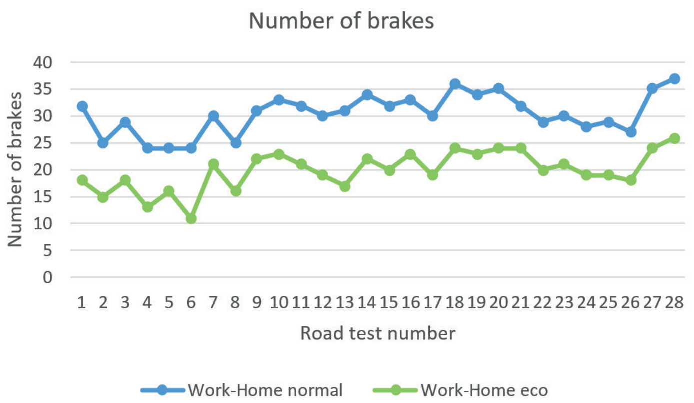

Fig. 2. The number of brakes applications depending on the driving style

Analyzing the data presented in Figure 2, the values of the use of brakes in eco-driving are much lower than in the normal driving strategy. In the case of the total number of brakes in the tests, a decrease by approximately 34.7% was recorded in the case of eco-driving. This state of affairs may be influenced by the fact that in the case of eco-driving, the driver observes the road situation better, uses engine braking more often and limits the excessive use of brakes. In addition, the amount of acceleration of the vehicle approaching the intersection is limited, the driver, for example, anticipates the change of the traffic light on the signaling device, which reduces the amount of intense braking.

Figure 3 shows the values of the total number of vehicle stops down to 0 km/h depending on the used driving strategies.

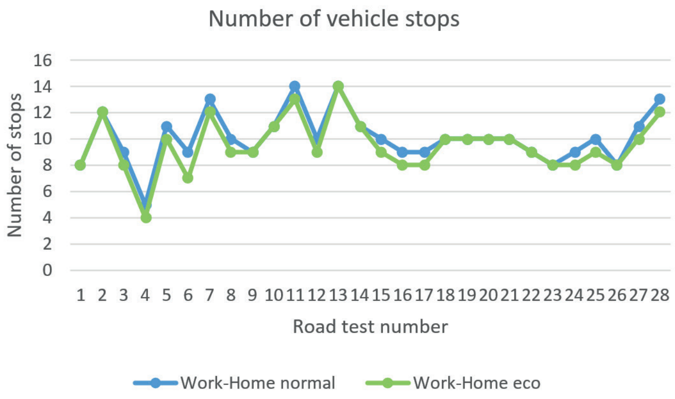

Fig. 3. The total number of vehicle stops down to 0 km/h during road tests

Based on the analysis of data in Figure 3, it can be concluded that in most of the test drives the number of stops was lower than in the normal driving strategy. The total number of vehicle stops down to 0 km/h takes into account e.g. traffic light stops, other intersections and, for stops before a pedestrian crossing. Based on the analysis carried out, we can conclude that when using eco-driving strategy, we maintain greater smoothness of traffic, which translates into a smaller number of vehicle stops than in the normal driving strategy.

Figure 4 shows a comparison of the number of vehicle stops at intersections with traffic lights for both driving strategies.

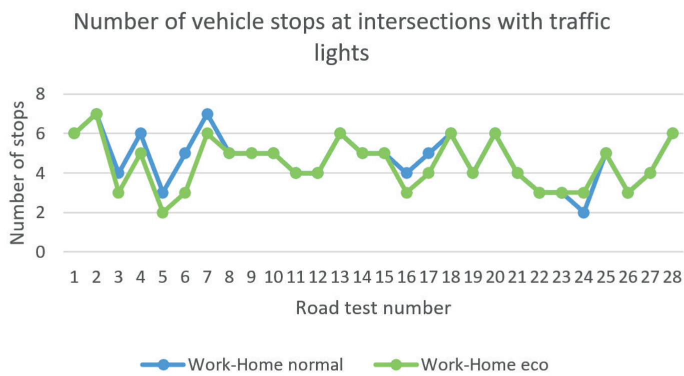

Fig. 4. The total number of vehicle stops at intersections with traffic lights

Analysing the data presented in Figure 4, it can be concluded that in most test drives the number of stops was comparable for both driving strategies (approximately 60%). 25% of the cases in the normal driving strategy had a higher number of vehicle stops at the intersection with traffic lights. In one test, the normal driving strategy had a lower volume than the eco-driving strategy. Smaller amounts of detentions occurred in 7 cases with eco-driving which strategy as in the case analysed earlier, indicates better smooth of traffic during eco-driving strategy.

Figure 5 shows the number of vehicle stops at intersections obtained in road tests for both driving strategies. Figure 6 shows the number of vehicle stops before pedestrian crossing obtained in road tests for both driving strategies.

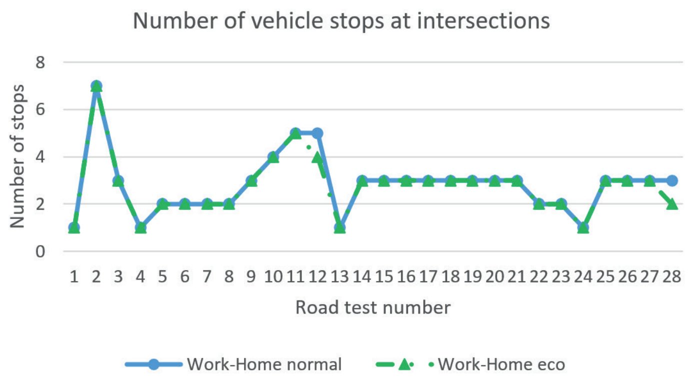

Fig. 5. The total number of vehicle stops at intersections

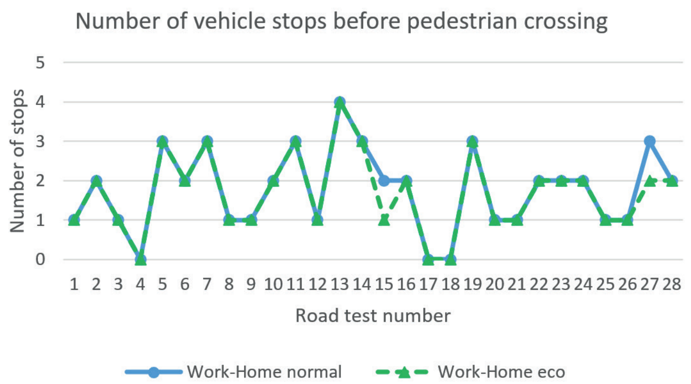

Fig. 6. The total number of vehicle stops before pedestrian crossing

Analyzing the data presented in the Figure 5 and Figure 6, it can be said that in most test drives the number of vehicle stops was comparable for both driving strategies. Only two tests in the normal driving strategy had a higher number of vehicle stops at the intersection and before pedestrian crossing. The obtained results indicate that the choice of driving strategy does not significantly affect these driving parameters.

Based on the analysis of the research results, it can be concluded that the use of the vehicle in the eco-driving strategy is more ecological. The obtained lower number of braking has a positive effect on the emission of dust from the friction elements in the vehicle and extends the brake operation time. Research related to the service life of brake systems was presented, among others, by [5, 6]. Summing up, it should be stated that the consistent change of habits and reactions of the driver, continuous learning and the use of eco-driving contribute to the reduction of the use of brakes and sudden braking due to a more conscious approach while driving the vehicle. Less activation of the braking system reduces the occurrence of high thermal loads and extends its life, and contributes to the reduction of pollutant emissions from this system.

As demonstrated, the greatest benefits of using the eco-driving strategy are visible in the lower number of brakes and stops of the vehicle, which may result from a better analysis of the driving situation by the driver. In addition, a better smoothness of traffic was noticed compared to the normal driving style, which is clearly visible in the number of stops of the vehicle at intersections with traffic lights. This situation results from the fact that the driver, using the eco-driving strategy, analyses the situation and does not accelerate, knowing that he will be approaching the intersection with the red light on. As a result, the vehicle moves slower, brakes the engine, and when it reaches the intersection, the traffic light turns green and instead of stopping at the intersection with traffic lights, the driver reduces gear and continues without stopping the vehicle. Recall that the tests were carried out on a routine route for the driver, i.e. the driver knew the timing of intersections and the changes of lights, which made it easier to predict the situation before the intersection. This also shows that it is possible to achieve a smoother ride for an eco-driving strategy.

4. Conclusions

This paper presents selected results of eco-driving a passenger car in the urban traffic along a routine route. It can be concluded that the greatest benefits of using the eco-driving style are visible in the lower number of brake applications and vehicle stops, which may result from a better analysis of the driving situation by the driver. In addition, a better flow of traffic in relation to the normal driving strategy was noted.

There was a significant reduction in the number of brakes by approximately 35%, during eco-driving strategy compared to normal driving strategy. The obtained results show the possibility of limiting the intensive braking, which makes it possible to extend the service life of the friction elements of the braking system and the emissions from this system. This is undoubtedly one of the benefits of eco-driving, as well as reducing fuel consumption, which is widely described in the available literature but was not the subject of this study. The aim of the work, which was to verify the possibility of limiting intensive braking and the number of braking thanks to the use of eco-driving, was achieved. The presented benefits are important for extending the service life of the braking system, which may encourage drivers to become interested in this driving style.

There were differences in the number of vehicle stops at intersections with traffic lights in favor of the eco-driving strategy. No significant differences in parameters were observed: vehicle stops before road crossings and vehicle stops before pedestrian crossings.

Summing up, it can be concluded that economical driving in urban traffic has great potential and it is worth using the eco-driving style in everyday commuting to work or school, that is, on a so-called routine route. It is therefore important to promote the eco-driving strategy in society, especially among drivers with little experience as well as for older drivers in order to improve traffic flow. Training courses for drivers in eco-driving should be introduced, unfortunately there is no such obligation in the applicable law, therefore more extensive action by the authorities is required in the field of training young drivers and training those with more experience.

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