A STUDY OF ECO-DRIVING POSSIBILITIES IN PASSENGER CARS USED IN URBAN TRAFFIC

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Abstract

During the operation of motor vehicles, their operational parameters change. This is related to the influence of operating and external factors on the combustion engine while driving. For many years, there has been a discussion on the improvement of the ecological properties of vehicles related to technical and legal issues as well as the technique of vehicle operation and use. The main aim of the article is to present the possibilities of using eco-driving in city traffic and its effects in comparison with the normal driving style. The article presents selected results of road tests of the passenger car. The results of studies of the influence of selected parameters, such as average speed, driving time, mileage, road type, number of stops, number of brakes, are presented. The object of the research was a passenger car powered by a spark-ignition engine, running in the so-called routine route, in a selected area of the city of Lublin in south-eastern Poland. The analysis shows that the use of eco-driving techniques has some benefits in urban traffic.

Keywords: ecology; driving style; fuel consumption; on-road testing

1. Introduction

The transport sector is influenced by a wide range of external social and economic factors such as demographics, the living standards of the population, urban planning, the organisation of production, structural changes in society and accessibility to transport infrastructure [56]. One of the trends of the last decade has been a significant increase in road traffic [30]. 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 [27]. Because of the narrow streets and the density of the existing buildings within the city, in most cases it is not possible to extend current infrastructure [20]. Due to infrastructure limitations and the growing motorisation index in many countries, especially in developing countries, problems with transport congestion are increasing. Road transport generates the highest social costs, including the costs of road traffic accidents [11, 53, 57], environmental degradation [33, 55] and congestion [21, 32]. Almost 3,700 people are killed daily all over the world in road traffic accidents

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involving pedestrians or different transport modes such as vehicles, buses, motorcycles, bicycles and trucks [52]. There are many scientific publications in literature concerning traffic safety issue [3, 8, 31], driver's reaction time [13, 19, 54], speed [14, 24] or legislation [29]. Motorisation index of passenger cars divided per 1,000 inhabitants is constantly growing [1]. This situation, together with the limitations of the infrastructure, causes an increase in the phenomenon of transport congestion in urban agglomerations. The traffic intensity in a given city is not distributed equally throughout the day and over the entire area [41]. Most of the city's inhabitants choose individual transport for their travels, which increases the volume of traffic on the regular network of connections. The presence of mass passenger flows in the city determines the pendulum principle of their formation in several directions of the regular route network at certain periods of the day, depending on the time of operation of these centres [23]. The problem of transport congestion has also been discussed in scientific publications [18, 25, 58]. Many researchers associate the phenomenon of transport congestion with environmental pollution. The emission of air pollutants from transport has a negative impact both on the environment and human health as well as on climate change [22, 48, 55]. It has been found that the emissions from transport comprise 26% of the total CO2 emissions in the EU [36]. There are many scientific publications in the literature about the impact of transport on the natural environment [9, 12, 33], including the limitation of climate change [4, 36, 55].

Despite many advanced works on mechatronics systems [10, 49] and autonomous vehicles all over the world [35, 44], people still make transportation decisions on a global scale. Among all the elements of the transport system, man has the greatest ability to adapt to changing current traffic requirements. Therefore, the behaviour of their vehicle on the road depends on decisions made by the driver. The factors that are directly influenced by the driver are as follows:
- driving economics - depending on the chosen of driving style;
- smoothness of ride and limiting the phenomenon of congestion;
- impact on the level of exhaust emissions, depending on the driving style and skills of the driver;
- impact on the emission of other pollutants (dust, noise);
- road traffic safety, reactions of other road users to the actions of the driver;
- comfort and costs of traveling by individual means of transport.

Due to existing problems in the transport sector, initiatives are taken to reduce these problems. One of the possibilities to improve the economy and ecology of vehicle use is to change the driving style. The driving style also affects road safety. A driving style that combines these factors is eco-driving. Eco-driving is understood as the improvement of driving technique due to the economic, ecological and operational benefits of the vehicle. Many researchers see the potential of eco-driving to: improve traffic safety [15, 40], reduce fuel consumption [43, 45, 50], slow the degradation of other vehicle components such as the braking system [6, 39], suspension [5] and tyres [38]. Vehicle fuel consumption in one of the most important operational characteristics of road vehicles [42]. Eco-driving is also responsible for analysing the situation on the road, anticipating the manoeuvres of other road users and skilful braking with the vehicle. Braking is a dynamic effect (process) that causes a vehicle's speed to change over time and along a certain route [37, 47]. More details about the idea of eco-driving, its benefits and challenges for improving road traffic can be found in the literature [2, 8]. The main principles of eco-driving are: smooth driving, moderate engine speeds (up to 3,500 rpm), engine braking and reducing engine running at idle speed, anticipation manoeuvres, greater concentration of the driver, route selection, control the correct pressure in the wheels of the vehicle, reducing use of air conditioning.

This article presents selected research results of passenger cars operating in urban traffic using an eco-driving style. The investigations were carried out in comparable traffic conditions, on the same section of road in the so-called "routine route" moving from home to work in the city of Lublin in south-eastern Poland. A passenger car powered by an internal combustion engine was used for the tests. The results of the impact of the eco-driving style on chosen parameters like average speed, time driving, number of stops, and number of braking incidences in comparison to a normal driving style are presents.

2. Methodology

The research was carried out at the same specified time of day and under comparable traffic conditions, on the same section of road and driving from home to work (routine route). In order to ensure comparable conditions, the middle days of the week from Tuesday to Thursday were selected and the weekend was omitted. Monday and Friday were excluded from the measurements due to relatively heavy traffic, which distorted the test results. During the ride, the driver's behaviour and various operational activities (e.g. accelerating, braking, stopping the vehicle, vehicle speed) were recorded. The results of road tests were analysed in terms of the benefits of eco-driving in relation to normal conditions. Normal conditions are defined as those in which the vehicle is steered without economic driving strategies.

The following parameters were taken into account in the research:
- number of vehicle braking incidences,
- number of incidences of the vehicle being stationary,
- number of stops at traffic lights,
- number of stops at intersections,
- number of stops at pedestrian crossing,
- maximum speed [km/h],
- average 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]. The 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 1,020 kg and the vehicle's weight was around 1,150 kg during the tests.

The test road is marked on the map shown in Figure 1. Point A is a beginning of the route, point D is end of the route (work place). The intermediate points (B and C) are larger intersections where the direction of the route changed. The route was mapped using the portal: (www.dojazd.org) [16]. The basic features of this route are shown in Table 1.

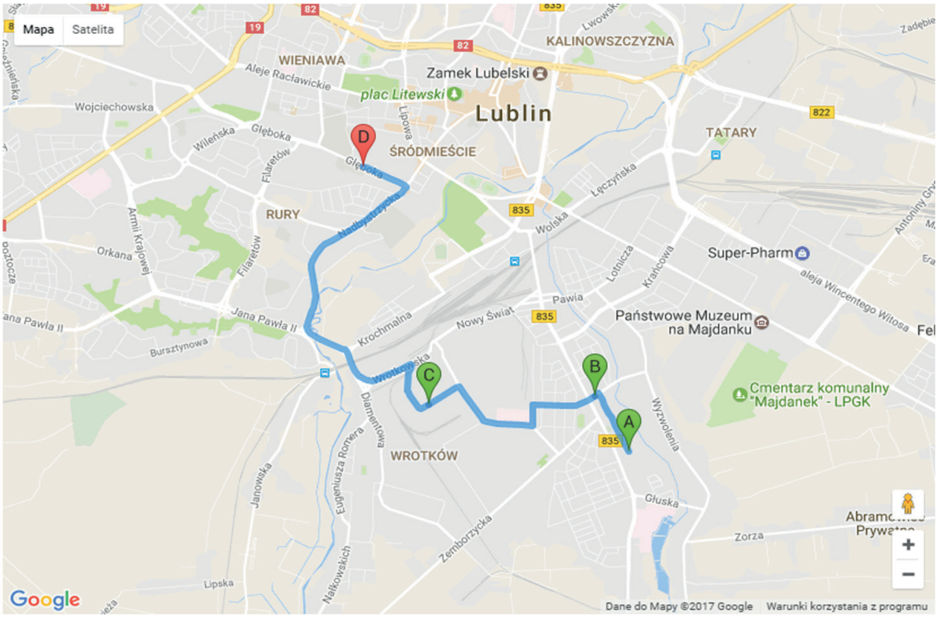

Fig. 1. Marked route from home – point A, to work – point D

Tab. 1. Basic data concerning the route from home to work

Route parameters	
length of the route [km]	7.7
number of intersections with traffic lights	5
number of pedestrian crossings	41
number of intersections without traffic lights	21
number of intersections with railway lines	1

3. Results and discussion

The analysis focused on the most important parameters that best illustrate the differences in both driving styles in the tested route section in urban traffic. Figure 2 shows results of the number of brake applications (understood as the number of brake pedal presses) depending on the current road situation. The presented values are for normal driving and the eco-driving style.

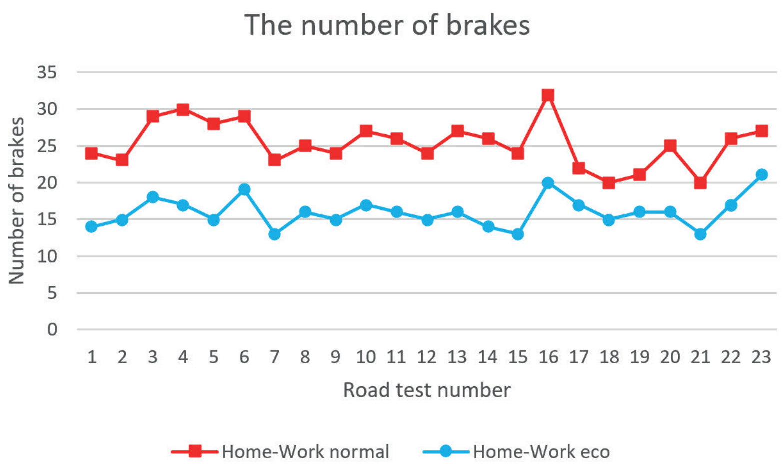

Fig. 2. The number of brake applications during road tests

Based on the analysis of data from Figure 2, it can be said that in the case of the eco-driving style, the amount of brake application is much smaller compared to the normal driving style. The reason for such a situation may be that by applying the principles of eco-driving, we better observe the traffic situation and predict the behaviour of other drivers more, for example, we evaluate the change of traffic lights earlier at the intersection, analysing the manoeuvre for overtaking or avoiding an obstacle. Therefore, we limit the acceleration of the vehicle, we decide to downshift faster, we brake the engine, which in turn reduces the amount of intensive braking of the vehicle. Thus, the total amount of braking in the road tests, is decreased by 36.8% when using the eco-driving style.

The total number of occurrences of stopping the vehicle depending on the driving style is presented in Figure 3. The total number of stops up to 0 km/h includes, among other stops, stops in front of traffic lights, other intersections and stops at pedestrian crossings.

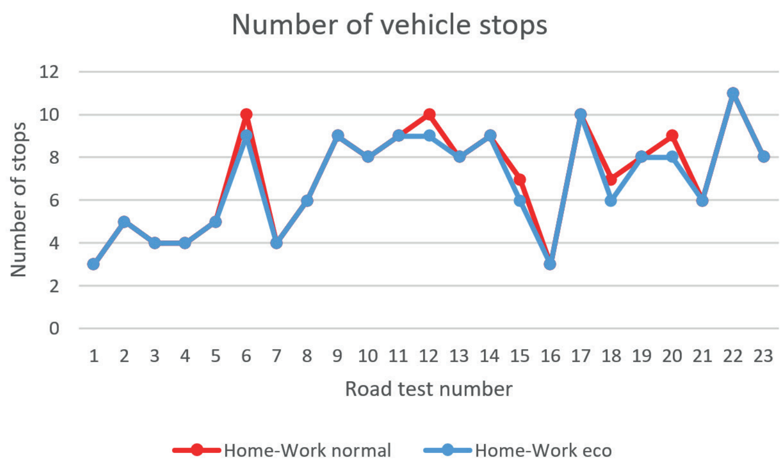

Fig. 3. The total number of vehicle stops during road tests

Analysing the data in Figure 3, it can be concluded that the number of occurrences of stopping the vehicle was comparable in both driving styles. It can therefore be said that the driving style does not significantly affect the overall number of vehicle stops in urban traffic. Probably, the situation would be different for aggressive driving, but this type of behaviour was not studied in this test. Aggressive driving affects fuel consumption and emissions as well as the technical conditions of the vehicle [45].

Figure 4 shows the average speed values obtained in road tests depending on the driving style.

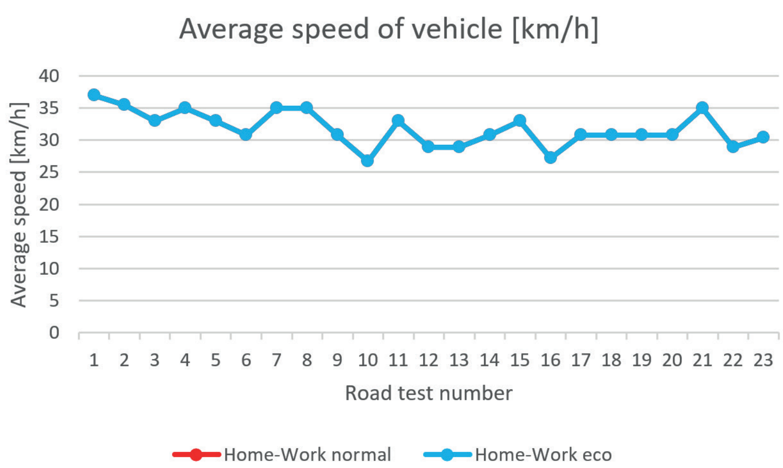

Fig. 4. Average vehicle speed values during road tests

As shown in Figure 4, the average value of the vehicle speed on the tested road section was comparable for both driving styles. Thus, we can say that the driving style does not affect the average speed value of the vehicle in these tests. A similar tendency was observed in the case of the obtained travel time value of the vehicle, which is shown in Figure 5. The same values of travel time were obtained in the case of both driving styles.

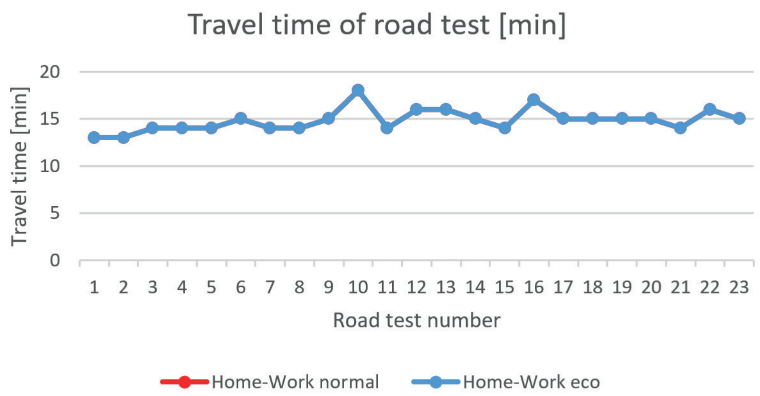

Fig. 5. Travel time values depending on driving style during road tests

Analysing the data shown in Figure 4 and Figure 5, it can be concluded that changing the driving style to eco-friendly does not adversely effect the average speed of vehicle and travel time in urban traffic conditions. In Figure 6, the elevation profile of the measured road is shown.

Fig. 6. Height above sea level change during road test

The beginning of the route is 182 m above sea level, and the end of the route is 184 m (see Figure 6). The maximum height of the route is 198 m above sea level. From the elevation profile of the measured route, we can read that the maximum slope of the route is 10.2% and -18.7%, while the average slope of the route is 1.7% and -1.7%. The maximum increase is 90.2 m, while the decrease is -88.3 m on the section of the measured route.

The presented analysis shows that the use of eco-driving principles has a positive effect on reducing the amount of excessive braking. This can result in extending the service life of the friction elements of the braking system and can thus also lower emissions from this system during vehicle operation. In addition, the eco-driving style does not change the average speed and does not extend the travel time, which were concerns among sceptical drivers with regard to using this driving style. The amount of fuel consumed may also be influenced by driving style [26, 51]. Based on the literature, it is known that an eco-driving style has a positive impact by reducing fuel consumption, which is indicated in research [4, 34, 46].

Barkenbus [4] suggests 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. It should be noted that the efficiency of a vehicle is not constant during its operation, but depends on the individual components of the driveline, which are related to vehicle speed and acceleration. Sivak and Schoettle [45] estimate a 45% reduction in fuel consumption in road traffic thanks to control of the following factors: aggressive driving, excessive engine speeds, route selection, engine settings, tyre maintenance, air-conditioning use, excessive idling, extra weight and incorrect engine oil. The influence of driving style on fuel consumption is noticeable in many reporting studies and fuel economy has also been achieved through the use of eco-driving habits [45, 50, 51]. In conclusion, we can say that the key to reducing fuel consumption is constantly changing the driver's reaction, learning and applying eco-driving habits.

The research of the Delhomme [12] showed that young and middle-aged drivers showed difficulties in adjusting to the eco-driving style, which may be due to the reluctance of respondents to learn. In road traffic, it is very easy to become distracted, which in turn may make it difficult to use eco-driving habits. Problems with concentration and perception of traffic signs are shown in research [17, 28]. The subject of distracting drivers from proper track driving has also been researched [54]. Using eco-driving is especially difficult at the very beginning of changing driving style, when we are at the initial stage of application.

4. Conclusions

This paper presents selected results of research concerning the eco-driving of a passenger car powered by an internal combustion engine in urban traffic. The main aim of the study was achieved, it has been shown that applicability of the eco-driving technique in routine route in urban traffic is possible.

The analysis of research results indicate there are no differences in parameters such as travel time and average vehicle speed between each driving technique.

A significant decrease has been shown in the number of braking incidences of more than 35% during an eco-driving style compared to normal driving style.

In the case of the number of vehicle stops, these values are comparable for both driving styles. Basically, there are slight differences during testing (1 vehicle stop).

Research has found that there are factors that influence eco-driving and that it is very easy to become distracted and revert to old driving habits. Driving in a traffic jam is one such situation, where long waiting times and short climbs can lead to the driver's nervousness and distraction.

To sum up, it can be concluded that economical driving in urban traffic has great potential and it is worth using an eco-driving style in everyday commuting to work or school. Further research should focus on the aspects related to distracting the driver from the eco-driving strategy, which was also signalised in the literature.

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