Article

Environmental Effects of Eco-Driving on Courier Delivery

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Abstract: In recent years, eco-driving has proven to be an effective tool for reducing fuel consumption and greenhouse gas (GHG) emissions. Until now, most research carried out has focused on ordinary drivers applying eco-driving techniques on their usual routes. However, there is little research on professional driver couriers. This research is aimed at analyzing the effects that eco-driving has on fuel consumption and GHG emissions on courier deliveries in small cities such as Cáceres (Spain). For this purpose, a real-life experiment was performed with professional drivers with Spanish post vans from the public sector company Correos. In the first period, driving was under normal conditions (non-eco), and after a theoretical training eco-driving course, there was a second driving period (eco). Driving parameters (speeds, accelerations, rpm, and consumptions) were recorded on all trips to analyze how effective the eco-driving was. The research concluded that eco-driving training does not correlate with more sustainable driving for professional drivers under pressure with the need to deliver packages on time. However, there is a trend in fuel savings when using higher capacity routes.

Keywords: eco-driving; courier delivery; professional driver; CO₂ emissions; fuel consumption

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1. Introduction

The transport sector accounts for 25% of total greenhouse gas (GHG) emissions and almost 40% of those are from different sectors. By categories of transport, road transport represents almost 95% of emissions, while those in other categories are lower [1]. Cars and vans accounted for 72.6% of GHG emissions from road transport in 2016 [2].

The Paris Agreement [3] set a goal of reducing GHG emissions by 40% in 2030 compared to 1990. In order to achieve this goal, the United Nations [4] warned that from 2020 carbon emissions will have to be reduced at a rate of 7.6% per year to meet the goal of limiting the increase in global average temperatures to 1.5 degrees above pre-industrial levels.

At COP-25 in Madrid (Conference of Parties of the United Nations Framework Convention on Climate Change) [5], 73 States, including Spain, have committed to being carbon neutral by 2050. For this purpose, Spain has set itself to reduce CO₂ emissions by one-third in the next decade, by doubling consumption of renewable energy by 2030.

In Spain, road transport is the main category of transport for both passengers and freight, representing more than 80% of total mobility nationally [6]. There are specifically national circumstances that have led to an increase in the share of the road transport category. First, there is the dispersed urban growth model in the case of passenger mobility. Second, it is a peripheral country in terms of freight mobility as it is located in the Iberian Peninsula. Furthermore, it is characterized by the preferential use of petroleum-derived fuels that represent more than 90% of total energy consumed in the transport sector in Spain [7].

GHG emissions corresponding to transport in Spain in 2014 were 77.2 MtCO₂-eq [8], having increased by almost 50% since 1990 due to increased demand for the mobility of passengers and goods.

Therefore, reducing GHG emissions is one of the goals of any country pursuing carbon neutrality by 2050. For freight transport, there are the following measures for reducing GHG emissions:

1. Fleet management system: companies which have used them have reduced emissions from their logistical processes by up to 2% each year [9].
2. Natural gas vehicles: in 2017, gas consumption grew by 9% in Spain and is expected to take off from 2020 [10].
3. Megatruck: according to a study by the European Commission [11], megatrucks (European Modular System Truck) can reduce fuel consumption by up to 20%, CO₂ by 20%, and emissions of other pollutants such as NO_x (nitrogen oxides) by 40%.
4. Eco-driving: according to the guide on Eco-Driving of Industrial Vehicles from the Institute for the Diversification and Saving of Energy of Spain [12], eco-driving enables average savings of 10% in fuel.

2. Literature Review

Eco-driving techniques include how to start the engine, when to start braking the vehicle, and maintaining a suitable speed, which are concepts that reduce fuel consumption and, thus, CO₂ emissions. In addition, they save both money and energy, require less maintenance, improve average speed, lessen the risk of accidents, and improve comfort. Eco-driving training programs carried out for individual drivers usually consist of two parts: theoretical and practical. In the practical part, the emphasis is on driving smoothly while maintaining a constant speed, changing gears at low revolutions per minute, and avoiding sudden acceleration/deceleration as much as possible [13].

Figure 1 shows a map made with the VOSviewer software (www.vosviewer.com) which used advanced layout and clustering techniques to show the existing relationships between keywords characterizing articles from the Scopus database. It has allowed identifying the main areas of research in eco-driving and fuel consumption.

Figure 1. Map of current research trends based on co-occurrence of keywords “eco-driving and fuel consumption” from the Scopus database in the years 2010–2020.

In the literature, eco-driving techniques [14] have shown different degrees of efficiency in saving fuel and GHG emissions depending on various external factors and the learning methods used. CO₂ emission reduction values range between 0.5% and 10% depending on the road type (urban roads or highways) [15]. Traffic intensity or slopes driven on are

factors that have a direct impact on consumption [16]. Therefore, the eco-driving techniques to be used are different depending on the characteristics of the city [17], or type of road travelled [18]. Selecting an ecological route (eco-routing) has also proven to be effective in saving fuel consumption and CO₂ emissions [19]. Better results have been obtained with communication between the vehicle and the infrastructure based on eco-driving guidance, increasing fuel savings to values around 20–40% [20].

Research made so far on these techniques has normally focused on non-professional drivers [21], in passenger cars on different types of road [22], vehicle or city [23]. Some research studied professional drivers, but they were not working in a courier company (Table 1).

Table 1. A summary of previous eco-driving training programs on professional drivers.

Reference Number	Year of Publication	Research Type	Fuel Consumption Reduction (%)
[24]	2007	Urban bus drivers in Greece. 15 km route designed for training purposes	10–15%
[25]	2013	Truck drivers in Germany	9.5%
[26]	2013	Drivers on one bus line. Swedish public transport operator. 54 drivers, 16 km route	6.8%
[27]	2013	Commercial vehicles in driving simulator experiment in Germany	6.0%
[28]	2013	Municipal drivers in City of Calgary (Canada). Fifteen drivers from the Development & Building Approvals Business Unit	4–10%
[29]	2014	34 professional drivers of the Urban Bus Company (EMTUSA) in the City of Gijon (Spain). Period of 12 months.	7%
[30]	2015	29 bus drivers with a simulator driver in Helsinki (Finland)	11.6%
[31]	2017	Lisbon urban bus transport operator (Portugal)	0.3–2%
[32]	2017	Public bus transport company. 3 drivers, 7.7 km in Novi Sad (Serbia)	11.71%
[33]	2019	16 bus companies. 880 professional drivers in Spain	10%
[34]	2019	Driving simulator. 8 taxi drivers in China	8.4%
[35]	2019	30 bus drivers in Belgrade (Serbia). Route length of 14 km	8.61%
[36]	2020	Public metrobus systems used by 250,000 passengers every day in Turkey. 15 months evaluation period	5%

Table 1 summarizes the results of fuel consumption savings with eco-driving performed with different types of professional drivers. For bus drivers, these savings range from 0.3 to 2% obtained in Portugal [31] to values of 10–15% in Greece [24]. Furthermore, Rutty et al. [28] studied the efficiency of eco driving with municipal drivers in Canada, where daily savings in consumption between 4 to 10% were gained. Yao et al. [34] studied eight taxi drivers with a driving simulator in China, obtaining savings of 8.4%. Nevertheless, none of these studies analyzed professional drivers from couriers driving under pressure to deliver packages on time.

Research on light commercial fleets showed a maximum fuel consumption savings of 7.6% in the U.K. [37] while in Germany negligible consumption reduction values were obtained [38]. These studies only focused on large cities, so the effect in small and non-congested cities must be researched with which the efficiency of eco-driving from these professional drivers can be compared. In light of the gap in knowledge in the literature, the objectives of this research are as follows.

1. To estimate consumption and emissions given off by couriers in normal driving and after attending a theoretical training course, with eco-driving in a small and non-congested city such as Caceres (Spain). To evaluate the reduction in fuel consumption and CO₂ emissions in eco-driving.
2. To evaluate the efficient of eco-driving by road type.
3. To study through surveys, the perception of professional drivers on eco-driving techniques and how they apply them to everyday driving.

For this purpose, the Spanish public sector courier Correos (Correos y Telégrafos S.A, <https://www.correos.es>) collaborated in the research. The city chosen was Caceres as it is small and non-congested.

After this introduction and literature review, Section 3 describes the methodology followed to perform the tests with professional drivers before and after attending eco-driving training. Section 4 describes the results obtained. Section 5 presents a discussion of the research and compares the results with those from other similar studies. Finally, the most outstanding conclusions from this research are included providing new ideas for future research.

3. Materials and Methods

Favorable results from previous research in eco-driving led to an eco-driving experiment on vehicles from professional companies in which fuel consumption has a direct impact on the financial performance of the company. To do so, a test was performed with four vehicles and five professional drivers from the company Correos in the city of Caceres.

The research was split into two phases: some field tests, and a subsequent study and analysis (Figure 2). In the first week of the field tests, drivers performed their respective routes under normal driving conditions (non-eco) and in the following week with eco-driving. In both methods of driving, the main driving data from the vehicles were recorded and stored (GPS positioning, speed, accelerations/decelerations, fuel consumption, etc.). In the second phase, a study of the data collected was made in order to analyze how effective eco-driving with professional drivers was.

Figure 2. Research framework.

3.1. First Phase: Collecting Data on the Activity of Vehicles on the Road

The test ran from mid-September 2019 to mid-October of the same year. It consisted of data collected through an OBD-Key device [39] installed in the vehicles, which stored different parameters on car activity in their respective delivery days. First, the drivers drove in their usual way, i.e., as they had driven until then (non-eco). After this initial data collection, the drivers attended a training session on eco-driving in order to adopt the typical attitudes for this way of driving (see Appendix A). Once they had been trained, the drivers began eco-driving. The same driving parameters were registered for purposes of comparison. At the end of each day, each driver was asked how they felt by way of a survey.

Driver commitment is required for performing the test successfully in this kind of experiment, i.e., the human factor is crucial in terms of the results and effectiveness of applying these techniques. Additionally, it should be clarified that the routes were not

predefined, as this is a characteristic of other studies [40]; rather, they were defined each day differently by the driver to optimize all deliveries during their working day. Therefore, they faced different traffic situations, which affected research variables such as speed, waiting times due to traffic congestion, or comfort. Driving should be carried out under different weather conditions, road types, or traffic congestion, as the research aims to obtain data on the overall efficiency of eco-driving in professional drivers.

3.1.1. Case Study: City of Caceres, Spain

Caceres is a city located in western Spain, with a population of approximately 96,000 inhabitants, covering an area of 30 km². It has a significant historical past, with a high density of monuments and a unique urban morphology characteristic of the Middle Ages. As a result, it was named a World Heritage Site by UNESCO in 1986 [41].

Cars and vans represent 55% of transport within the city. Despite being hilly, pedestrian walking accounts for one-third and public transport represents only 12% of total transport [42]. The city has three peak hours: between 8:00 am and 9:00 am, the school run and the start of the working day (10% above average); 2:00 pm, lunch break (28% above average); and between 6:00 pm and 7:00 pm, returning home (15% above average) [43].

Sustainable growth for the city involves implementing measures that promote using public transport and pedestrian mobility. Although environmental protection and emission reduction policies have already been applied in the historic center of Caceres (pedestrianizing the historic center), pedestrian spaces that exclude car movements must be extended to reach new and better sustainability goals.

3.1.2. Routes and Traffic Conditions

Caceres is a small city that can be crossed in less than 15 min. As mentioned above, the routes do not adhere to defined itineraries, but rather follow that of a professional driver on a normal delivery day. That is distributed throughout the city, travelling along different types of urban roads (Figure 3).

Figure 3. Global vision of the routes of one of the drivers with normal driving (non-eco) (left) and eco-driving (right).

Five different types of road (Figure 4) [44] are defined to characterize the different sections and analyze specific shorter routes (micro-trips):

1. Local street: this type of urban road can be seen inside the city. The road has one lane per direction, with no median or parking spaces. The speed limit is 50 km/h and it is usually congested.

2. Urban collector: a road that surrounds the center of the city and connects its hubs. It is made up of two lanes each way, a median, and with parking spaces on each side. The speed limit ranges between 30 km/h and 50 km/h and it is sometimes congested.
3. Perimeter road: former city bypass now integrated into the urban network. It has a dual carriageway with two lanes in each direction separated by a double continuous line or median. The speed limit is 50 km/h, and there is hardly any traffic congestion.
4. Bypass: an outer ring road surrounding the outskirts of the city. Intersections are arranged with roundabouts and pedestrian crossings are regulated through traffic lights. Speed limits are between 40 and 80 km/h. It is never congested.
5. Interurban road: roads located outside the boundaries of the urban area that connect external points to it, whether they are smaller population centers, industrial centers or other national roads or highways. Speed limits vary between 50 and 90 km/h and traffic usually flows very well with no congestion.

Figure 4. Road types travelled (source: Google Maps).

3.1.3. Driver Selection, Eco-Driving Training and Dates

To carry out the experiment, five drivers were selected from the delivery company of Correos in Cáceres. All drivers were male between the ages of 35 and 60, so the sample was representative in terms of age, but not in gender. During the first week, the trips these drivers made while driving as usual (non-eco) were recorded. Subsequently, the selected drivers received theoretical training on eco-driving techniques in order to implement them the following week. All trips made with eco-driving were recorded in the same way as previously with “non-eco” driving.

Work hours were divided into two time bands corresponding to the morning and afternoon work shifts: the first one was from 7:00 am to 2:00 pm and the second was between 2:00 pm and 9:00 pm. Four drivers performed the experiment in the first shift, while there was only one driver in the afternoon.

The experiment with standard driving (non-eco) took place between 23 September and 2 October 2019, and eco-driving was studied between 9 and 18 October of the same year. Between both periods, eco-driving training was given to the drivers.

3.1.4. Collection of Experimental Data

In the field test, commercial vehicles were used, and in this case they were diesel vans with similar technical characteristics. Three of them belonged to the Kangoo range from the Renault make and the fourth was the Partner range from Peugeot (Table 2). Commercial vehicles represent approximately 20% of cars and vans in service in Cáceres [45].

Table 2. Technical characteristics of the vehicles used in the research [46].

Features	Peugeot	Renault
Full name	PARTNER 1.6 HDi 75	KANGOO 1.5 DCi 70
Gear shift type	Manual (5)	Manual (5)
Maximum authorized mass	1960	2956
HP power	75	70
Dimensions (L × W × H) (mm)	4380 × 2890 × 1801	4213 × 2133 × 1799
Seats	2–5	2–5
Emissions (g de CO ₂ /km)	143	147
Classification by relative consumption	C	D

3.1.5. Measurement of Variables

Modern vehicles enable many aspects of running a vehicle to be monitored and visualized through the on-board diagnostic (OBD) system. This is carried out using electronic control units with which the engine, transmission, brakes, and other functions can be managed.

The OBD-key is a device that plugs into the vehicle's data link connector with which information from the vehicle's OBD can be captured. This information is sent through a mobile application [47] to a smartphone via Wi-Fi (frequency of 1 Hz) where the information is stored and subsequently transferred to a computer to process all the recorded data. With this device, 128 instantaneous parameters can be obtained such as GPS position, speed, acceleration, revolutions per minute (rpm), fuel consumption (L/s), and CO₂ emissions (g/s). The operating procedure is shown in Figure 5.

The effects of eco-driving will be evaluated first by comparing fuel consumption and CO₂ emissions and secondly, by analyzing the driving parameters with the highest influence on fuel consumption. According to Coloma et al. [48], and subsequently Lois et al. [49], the parameters which account for over 80% of fuel consumption are slope, average speed, average rpm, and average accelerations and decelerations. In addition to these values, other parameters are recorded to characterize different routes by location (GPS positioning) and traffic situation (95th percentile of instant recorded speed). The parameters listed below were finally used for the analysis before and after the drivers underwent eco-driving training:

1. GPS position (longitude and latitude) and distance travelled (km).
2. Travel time (h) and V_{95} (km/h).
3. Maximum and average speed (km/h).
4. Maximum and average rpm.
5. Maximum and average accelerations and decelerations (m/s²).
6. Fuel consumption (L/100 km) and CO₂ emissions (g/km).

Data on fuel consumption and CO₂ emissions take into account the slope value every second. However, to compare the drivers in eco and non-eco-driving mode, the slope value

was discarded, as the average slopes obtained for all routes were 1.9% and the maximum was only 2.9%.

Figure 5. Outline of the data collection and storage system process.

3.2. Second Phase: Analysis and Study of the Collected Data

In a laboratory, the stored data were received and processed from the OBD-Key. These data were filtered to remove erroneous registrations and stops when making deliveries. Subsequently, the different selected parameters were discretized and organized in order to calculate sums, averages, weights, or unit changes. Results were obtained and enabled comparisons between parameters and formulating reliable conclusions.

Once these data were processed, several documents were created which belonged to each driver and contained all the parameters monitored by the OBD-Key and recorded per second. From this information, the representative driving parameters of each working day for each driver in both driving modes (eco and non-eco) were set out on a spreadsheet.

After these spreadsheets were created, eco and non-eco-driving among the same drivers were compared. As explained, research was mainly looking for data on fuel consumption and CO₂ emissions and also to compare the parameters with the highest influence on consumption such as speed, rpm, and average acceleration/decelerations. As each driver travelled different distances and drove at different speeds, the consumption and emissions parameters weighted with respect to the time and distance travelled each day had to be obtained. In this way, fuel consumption values per 100 km (L/100km) and CO₂ emissions per kilometer (g/km) were found.

Later, sections of short routes made by vans (micro-trips) were analyzed with the data set obtained. For this purpose, the start and end time were obtained on different types of road travelled in the delivery routes. Geolocation analysis and storage software [50] were used to graphically represent routes and the main driving parameters at each point of the trip. With this process, the benefits of eco-driving for different types of road (micro-trips) could be studied. Figure 6 summarizes the process carried out.

Finally, a survey was carried out among drivers to assess the mood and attitude of the driver to using eco-driving techniques (see Appendix B). Once the data collection and analysis had been completed, the results showed satisfactory conclusions for this research.

Figure 6. Analysis and study of the collected data.

4. Results

Statistical data from the experiment have been included in Table 3.

Table 3. Distances and time travelled. Deliveries made.

Driver	Driving Mode	Distance Travelled (km)	Driving Time (h)	Deliveries No.
1	Non-eco	115.1	35.6	223
	Eco-driving	131.4	26.8	221
2	Non-eco	80.1	11.4	156
	Eco-driving	215.2	41.3	363
3	Non-eco	123.1	33.1	266
	Eco-driving	167.3	34.5	340
4	Non-eco	96.8	31.7	328
	Eco-driving	45.8	11.2	133
5	Non-eco	176.8	24.8	245
	Eco-driving	139.2	23.4	277
Partial	Non-eco	591.9	136.6	1218
Sum	Eco-driving	698.9	137.2	1334
Total	Non-eco + eco	1290.8	273.8	2552

Time deliveries for eco and non-eco-driving are similar (less than an hour apart). However, in eco-driving, 100 more kilometers were driven and over 100 packages distributed. Primarily, this was not due to the driving mode, but rather to the nature and location of the deliveries made. In eco-driving, more deliveries could be made, probably due to the reduction in waiting times, either because of the traffic situation, or the needs of the final recipients.

A total of 2544 deliveries have been registered, of which 95.28% have been residential and 4.72% industrial. Regarding the ages of the recipients, we registered a total of 2424 deliveries of which 47.44% were older than 45 years and 52.56% younger. Due to new

technologies, young people are the ones who most demand parcel services. However, in our study, the percentage of those over and under 45 years is very similar.

4.1. Eco-Driving Test

4.1.1. Driving Parameters

Table 4 shows the main driving parameters recorded by driver and for non-eco and eco-driving modes.

Table 4. Driving parameters for different drivers and driving mode.

Parameter	Driving Mode	Driver				
		1	2	3	4	5
Maximum speed (km/h)	Non-eco	41.7	38.8	47.1	31.7	61.1
	Eco-driving	48.5	51.1	51.8	30.0	49.2
V_{95} (km/h)	Non-eco	38.2	35.6	42.5	28.9	55.6
	Eco-driving	44.6	44.5	47.0	28.3	44.7
Average speed (km/h)	Non-eco	16.8	17.3	19.9	15.3	30.3
	Eco-driving	19.5	18.9	23.7	15.4	25.8
Average rpm	Non-eco	1164	1619	1225	1209	1745
	Eco-driving	1279	1563	1267	1286	1412
Maximum rpm	Non-eco	2144	3172	2849	1956	3004
	Eco-driving	2348	3096	2620	2012	2366
Average positive acceleration (m/s^2)	Non-eco	0.6	0.4	0.7	0.4	0.9
	Eco-driving	0.6	0.6	0.7	0.4	0.8
Average negative acceleration (m/s^2)	Non-eco	−0.6	−0.4	−0.7	−0.4	−0.9
	Eco-driving	−0.6	−0.7	−0.7	−0.4	−0.8
Maximum positive acceleration (m/s^2)	Non-eco	2.1	1.9	2.9	1.5	4.1
	Eco-driving	2.2	2.9	2.9	1.3	3.2
Maximum negative acceleration (m/s^2)	Non-eco	−2.0	−1.8	−2.5	−1.6	−4.0
	Eco-driving	−2.3	−2.8	−2.6	−1.4	−3.5

In most of the research published in the literature, eco-driving produces reductions in rpm, speed, and accelerations/decelerations [51,52]. From the results obtained, it can be concluded that only driver 5 improves his driving parameters with eco-driving. Maximum and average speeds, rpm, and accelerations increase with eco-driving in the parameters for the other four drivers. Congestion or the stress involved in delivering packages in the shortest possible time means that most professional drivers in the experiment did not obtain improvements in these parameters when eco-driving.

4.1.2. Consumption and Emissions

Table 5 shows estimated fuel consumption and CO₂ emissions for each driver and both driving modes (non-eco and eco-driving).

Table 5. Fuel consumption and CO₂ emission for driver and driving mode.

Parameter	Driving Mode	Driver				
		1	2	3	4	5
Consumption (L/100 km)	Non-eco	6.71	6.16	6.15	8.93	5.99
	Eco-driving	6.26	6.18	5.54	8.48	6.95
CO ₂ emissions (g/km)	Non-eco	208.7	191.0	187.2	271.2	188.8
	Eco-driving	193.3	195.1	168.4	259.2	219.9

Emission ratios differ according to the technical specifications of the vehicle, as well as fuel consumption, as each driver used different routes and drove in a different way.

Consumption and emission savings with eco-driving are represented in Figure 7.

Figure 7. Savings in fuel consumption (figure up) and CO₂ emissions (figure down) between non-eco and eco-driving.

Fuel consumption and CO₂ emissions show that eco-driving in small cities is inefficient. With the only driver to have eco-driving parameters, there was higher average fuel consumption and CO₂ emissions. Conversely, three of the other four drivers with no eco-driving parameters showed a reduction in fuel consumption and emissions. This shows that in small cities, high speeds mean short traveling times, which, in turn, reduce average fuel consumption (L/100 km) and average emissions. Eco-driving usually reduces speeds and acceleration, but in small cities where routes are very short, it does not sufficiently reduce instantaneous consumption, and this means longer driving times produce higher average fuel consumption (L/100 km) and, as a consequence, higher CO₂ emissions.

4.2. Efficiency of Eco-Driving in Micro-Trips

An analysis by type of road travelled (local, collector, perimeter, bypass, and inter-urban) was performed to study how effective eco-driving professional drivers based on type of route travelled was. For this purpose, eight different small routes were selected (micro-trips), with different types of road, which were easily located and widely used by drivers in their daily deliveries. Micro-trips locations are represented in Figure 8.

Figure 8. Micro-trips location scheme (source: Google Maps).

Selected micro-trips are routes shared by most of the drivers. An analysis was performed from the data from all drivers who had taken these routes, both in their normal style (non-eco) and in eco-driving. The results obtained were used to verify how efficient eco-driving had been by type of road travelled and not by drivers studied in the previous section. Characteristics of the selected micro-trips are attached in Table 6.

Table 6. Characteristics of the selected micro-trips.

Road Type.	Route No.	Description	Section Length	Speed Limit
Local	1	One lane for each direction	550 m	50 km/h
Collector	2	Two lanes each way separated by median. Parking on both sides	600 m	30–50 km/h
	3	Two lanes each way separated by median	900 m	30–50 km/h
Perimeter	4	Two lanes each way separated by median. Parking on both sides	950 m	50 km/h
	5	Two lanes each way separated by median. Parking on both sides	1200 m	50 km/h
Bypass	6	Two lanes each way separated by median	1000 m	50–80 km/h
	7	Two lanes each way separated by median	2200 m	50–80 km/h
Inter-urban	8	Two lanes each way separated by median	950 m	80 km/h

Two micro-trips have been selected for collector, perimeter, and bypass types of road. For the local and inter-urban road, only one section of these was found to provide enough data for the drivers in both driving modes.

A total of 136 deliveries have been studied (74 in non-eco and 62 in eco-driving mode). In addition, 72.2 km (40.1 non-eco; 32.1 eco) has been covered in a total of 125.35 min (70 in non-eco and 55.3 in eco mode). The number of kilometers and deliveries made in non-eco mode are greater than those made in eco-driving mode as drivers did not travel predetermined routes and kilometers driven in eco and non-eco mode do not need to match.

Driving parameters recorded in the micro-trips before and after eco-driving training are included in Table 7.

Table 7. Driving parameters on selected micro-trips.

	Driving Mode	Local	Collector		Perimeter		Bypass		Inter-Urban
		Route 1	Route 2	Route 3	Route 4	Route 5	Route 6	Route 7	Route 8
Maximum speed (km/h)	Non-eco	51.4	39.9	65.9	56.5	76.9	86.8	69.5	88
	Eco-driving	67.8	45.3	41.7	62.8	70.6	80.1	63.5	51.4
V95 (km/h)	Non-eco	50.5	37.5	63.6	52.1	75.4	84.8	66.2	86.8
	Eco-driving	66.4	43.8	41.1	60.6	69.4	79.0	62.9	51
Average speed (km/h)	Non-eco	39.6	24.3	37.2	34.6	57	59.1	50.9	73.6
	Eco-driving	44.9	26.0	26.9	40.4	42.8	64.7	46.4	45.5
Maximum rpm	Non-eco	2520	2309	2296	2890	2373	3135	2885	2859
	Eco-driving	3205	2633	2160	2447	2427	2592	2656	2235
Average rpm	Non-eco	1870	1168	1523	1800	1746	2062	2081	2154
	Eco-driving	2428	1337	1424	1713	1480	1882	2089	1834
Maximum positive acceleration (m/s^2)	Non-eco	1.7	2.0	2.4	3.0	1.9	1.8	2.9	1.8
	Eco-driving	2.2	3.0	1.1	2.3	1.9	1.6	2	0.8
Maximum negative acceleration (m/s^2)	Non-eco	−1.2	−1.5	−2.7	−3.4	−2.7	−3.2	−2.7	−2.7
	Eco-driving	−1.8	−2.2	−1.5	−3.7	−2.4	−1.7	−3.6	−1.3
Average positive acceleration (m/s^2)	Non-eco	0.6	0.6	0.6	0.9	0.7	0.6	1	0.6
	Eco-driving	0.7	0.7	0.3	0.8	0.7	0.6	0.8	0.3
Average negative acceleration (m/s^2)	Non-eco	−0.5	−0.5	−0.7	−0.8	−0.8	−0.8	−0.8	−0.8
	Eco-driving	−0.6	−0.6	−0.3	−0.8	−0.7	−0.6	−1	−0.3

Analyzing the results, eco-driving style can be seen in the routes with higher capacity and less congestion (bypass and inter-urban). Congested urban routes (local and collector) increase speed, rpm, and acceleration in eco mode, so using eco-driving techniques has not been viable on these types of road. Perimeter gives varying results that make it difficult to rate the driving style performed. In Route 5, there seems to be an eco-driving style, but not in Route 4.

Research made on different types of road normally indicates that eco-driving reduces speed, rpm, and accelerations [53]. However, there are other studies which show that on congested roads, eco-driving does not reduce these parameters [54]. Table 8 displays consumption and emissions estimated for the selected micro routes.

Table 8. Consumption and emissions estimation on the selected micro-trips.

	Driving Mode	Local	Collector		Perimeter		Bypass		Inter-Urban
		Route 1	Route 2	Route 3	Route 4	Route 5	Route 6	Route 7	Route 8
Consumption (L/100 km)	Non-eco	2.1	2.2	8.8	6.1	8.4	4.6	2.7	4.5
	Eco-driving	2.9	3.1	10.1	6.0	8.4	4.4	2.6	4.2
CO ₂ emissions (g/km)	Non-eco	63.6	70.7	154.8	188.5	109.4	146.1	77.8	112.5
	Eco-driving	88.2	96.4	187.4	186.3	109.3	138.5	77.6	97.0

Fuel consumption and CO₂ emissions are in keeping with the driving parameters performed. Routes with higher capacity and less congestion (bypass and inter-urban) reduce fuel consumption and CO₂ emissions when driving in eco mode. These savings with eco-driving are represented in Figure 9.

Figure 9. Micro-trips consumption (figure up) and CO₂ savings (figure down).

Results on micro-trips show that eco-driving is more effective on less congested roads with higher capacity (bypass and inter-urban). Urban roads more prone to traffic congestion (local and collector) are not effective in saving fuel and CO₂ emissions in eco mode. With the perimeter as it mixes urban and peri-urban roads, it is unclear whether eco-driving is beneficial. Therefore, professional drivers are recommended to choose the least congested and highest capacity routes to make it more effective.

4.3. Surveys

Eco-driving needs driver commitment in order to incorporate it into their daily driving techniques. There are several studies on eco-driving which reveal there is a direct relationship between the personality of the drivers and their environment (physical, psychological and psychosocial characteristics) and how effective this driving mode is [55,56].

Table 9 shows the results of the surveys carried out with professional drivers after the delivery shifts.

Table 9. Survey conducted with drivers on all registered trips.

Questions	Driving Mode	Surveys No.	Answers						
			1	2	3	4	5	6	7
Driving has been: Easy (1)–Hard (7)	Non-eco	18	15	1	1	1	0	0	0
	Eco-driving	15	15	0	0	0	0	0	0
Driving environment has been: Easy (1)–Hard (7)	Non-eco	18	12	2	3	1	0	0	0
	Eco-driving	15	10	4	1	0	0	0	0
When driving you were: Bored (1)–Amused (7)	Non-eco	18	3	1	1	1	2	8	2
	Eco-driving	15	3	0	1	0	0	6	5
When driving you were: Relaxed (1) –Stressed (7)	Non-eco	18	5	8	1	3	1	0	0
	Eco-driving	15	6	5	1	0	0	1	2

Most surveys (15 out of 18) considered driving easy. This came as no surprise as they are professional drivers. However, driving conditions were also “easy”, which means that traffic congestion and other external agents did not affect the way they drove.

Mood when driving hardly varied between normal driving and eco-driving. Contrary to what might be expected—that professional drivers would get bored when changing their driving style—most surveys (10 out of 15) actually felt amused while driving. Three of them did become bored, but this was the case in both eco and non-eco drives. This seems to indicate that the driving mode professional drivers adopt do not influence their mood.

Finally, we saw if the driving mode stressed the professional driver. The results show that most of them (13 of 15) felt relaxed during both driving modes, which means that eco-driving did not make them more stressed. However, their need to deliver within a certain deadline did cause professional drivers stress and it is very difficult for them to modify their driving style with eco-driving techniques.

5. Discussion

5.1. Research Limitations

This research studies the efficiency of eco-driving by comparing consumption and CO₂ emissions before and after a theoretical driver training. OBD devices have proven not to be very accurate in their measurements, but they have been used in this research as they are very easy to install and provide values that can be used to compare both types of driving.

In order to check the effectiveness of eco-driving techniques, a test should be done on a specific road section and under the same weather and traffic conditions. However, our research seeks to know if eco-driving techniques are effective for professional drivers in their daily deliveries. Therefore, the test must be carried out in real conditions, thus using different types of road and under different weather or traffic conditions. The problem is

that the results of the study of the efficiency of eco-driving techniques can be influenced by the different levels of traffic congestion and the weather conditions, and not by the driving mode used in the delivery. In future research, it may be good to carry out the experiment simultaneously with professional drivers who have received training in eco-driving techniques and drivers who have not received this training in order to compare the results with the same traffic and weather conditions.

Test has been made with four drivers in the morning shift and only 1 in the afternoon shift. Correos is a public courier company, so they work mainly during the morning. We also wanted to take data in the afternoon so that in future research we could analyze the efficiency of both shifts separately. On the other hand, drivers' ages ranged from 35 to 60, but they were all male. It would be necessary to analyze the efficiency of eco-driving by different age groups and also a new test with female drivers to check if the efficiency is similar in all cases or not.

Finally, drivers knew that they were being monitored before and after training. We wanted to know if by modifying the way of driving we could reduce fuel consumption and emissions. We were not able to elucidate if this behavior was maintained over time or was only carried out during the experiment. On the other hand, professional drivers may not be motivated enough to change their driving techniques as they have not been incentivized, so it would be interesting to know if incentives to save fuel (economic and non-economic) would change the results.

5.2. Results Discussion

Eco-driving usually reduces speed and acceleration, but in small cities where routes are very short, it does not sufficiently reduce instantaneous consumption, and this means longer driving times produce higher average fuel consumption (L/100 km) and, as a consequence, higher CO₂ emissions. This assertion is in keeping with Schall et al. [38], as they did not observe any savings in fuel consumption with eco-driving with a courier in Munich (Germany). However, these results clashed with most research carried out so far with non-professional drivers, since they show favorable results in consumption with eco-driving in both large and small cities, e.g., Dahou [57] reached fuel savings of approximately 20% with eco-driving in 10 cities in Tunisia. Furthermore, Andrieu et al. [58] obtained fuel savings of 11.3% in Pontchartrain, a small town in France. Tests carried out with simulators have also obtained good results with fuel savings of 5% reaching values of 20–40% with automated vehicles [59].

Results on micro-trips show that eco-driving is more effective on less congested roads with higher capacity (bypass and inter-urban). Therefore, professional drivers are recommended to choose the least congested and highest capacity routes to make it more effective. Coloma et al. in Caceres [60], and later Yang et al. in Madrid [61], obtained similar results to those found in this research, as fuel savings increased with road capacity. However, there are also other studies [62] which show that high capacity but congested roads are inefficient with eco-driving.

Surveys seems to indicate that the driving mode professional drivers adopt do not influence their mood. In contrast, with other research with non-professional drivers, driver boredom rose by 15% when driving in eco mode [60]. On the other hand, eco-driving did not make drivers more stressed. Garcia et al. [63] observed that non-professional drivers did not become more stressed when they drove in eco mode either. Nevertheless, their driving was more efficient (in fuel savings and CO₂ emissions) when drivers were younger, so driving schools need to provide training in these techniques [64].

6. Conclusions and Future Research

Developed countries try to promote efficient road management by using technologies that reduce GHG emissions in cities, implementing driving modes for drivers and sustainable travel decisions. Cities have different methods for achieving these environmental goals, but none can be reached successfully without driver cooperation. Environmental

policies must be accepted by the general public, and some of them fundamentally depend on the way they drive (eco-driving) and how they plan their trips (eco-routing). Research to date on eco-driving has generally focused on large cities due to their severe congestion problems. Nevertheless, small cities also face these issues and must help reduce GHG emissions, which is a worldwide objective.

In this research, a study was performed on the effectiveness of eco-driving with professional couriers in a small and non-congested city such as Cáceres. The results obtained confirmed that eco-driving with courier delivery does not generally lead to average fuel savings per vehicle. An analysis on micro-trips reflects a trend in fuel savings as road capacity increases. Figure 10 summarizes the main conclusions from this research.

Figure 10. Main conclusions from the research.

In future research, the effects of eco-driving on professional drivers could be studied with incentives (monetary and non-monetary) as Schall and Mohnen [65] achieved fuel savings of around 5% with the drivers of a fleet company who had received incentives. Other types of vehicle widely used in courier delivery such as motorcycles could be studied as well [66]. Moreover, the effect of eco-driving in electric vehicles also needs to be observed. These kinds of studies require theoretical models for energy consumption such as Vehicle Specific Power (VSP) [67].

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Appendix A. Eco-Driving Course Content

1. Transportation and energy issues.
 - 1.1. Energy consumption in Spain.
 - 1.2. Problems generated by CO₂ emissions.
2. Fundamentals of fuel consumption.
 - 2.1. Fuel consumption in road transport.
 - 2.2. Energy saving in transport.
3. Use of engine and its relationship with consumption.
 - 3.1. Efficient driving concept (Eco-driving). Contributions of eco-driving.
 - 3.2. The energy flow in the vehicle. Fuel consumption and power.
 - 3.3. Idle effect.
 - 3.4. Drag.
4. Explanation of eco-driving techniques. The driver's attitude.
 - 4.1. Prominence of the driver's attitude.
 - 4.2. Concepts associated with eco-driving and main rules.
 - 4.3. Relationship between fuel consumption and speed.
 - 4.4. Fuel savings in high gears.
5. Eco-driving from the vehicle point of view. Practical training.
 - 5.1. Sections with slope positive or negative.
 - 5.2. Curves.
 - 5.3. Use of air conditioning, vehicle window, tire pressure, engine maintenance, vehicle load and accessories.

Appendix B. Survey Template

Questions	Answers						
	1	2	3	4	5	6	7
Driving has been: Easy (1) – Hard (7)							
Driving environment has been: Easy (1) – Hard (7)							
When driving you were: Bored (1) – Amused (7)							
When driving you were: Relaxed (1) – Stressed (7)							

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