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ECOLOGICAL DRIVING ASSESSMENT IN URBAN ENVIRONMENT: CASE STUDY IN THE CITY OF RETHYMNO IN CRETE, GREECE

ΜΕΤΑΠΤΥΧΙΑΚΗ ΔΙΑΤΡΙΒΗ

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ΣΜΑΡΑΓΔΑΚΗ ΆΓΓΕΛΟΥ

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ΑΦΙΕΡΩΝΕΤΑΙ

Στους γονείς μου

Ευχαριστίες

Πρωτίστως, θα ήθελα να ευχαριστήσω ιδιαίτερα τον επιβλέπον Καθηγητή της διπλωματικής μου εργασίας κ. Θεοχάρη Τσούτσο για την αμέριστη στήριξη και την άψογη συνεργασία μας. Ευχαριστώ τον Αν. Καθηγητή κ. Τρύφων Δάρα , κα. Αν. Καθηγήτρια Διμέλλη Δέσποινα μέλη της τριμελούς εξεταστικής επιτροπής για τη συνεργασία μας και τα εποικοδομητικά σχόλια και παρεμβάσεις πάνω στην διατριβή μου. Ιδιαίτερα, ευχαριστώ πολύ για την αμέριστη συμπαράσταση τον Φίλο και υποψήφιο διδάκτορα κ. Νικόλαο Σηφάκη.

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Abstract

The transport sector is considered one of the most polluting and is responsible for about 20.5% of carbon dioxide (CO_2) emissions worldwide. 25% of this percentage concerns emissions from the road transport sector worldwide, while in 2016, 21% of the total CO_2 production rate in Europe was due to this sector. Ecological driving is inextricably linked to fuel economy, reduced emissions and road safety during land transport. Several factors can affect ecological driving and they should be given the necessary attention and proper information to drivers. In Greece, and specifically, in Crete, economical and environmentally friendly driving can be considered quite difficult due to the rocky terrain of the island, with the constant fluctuations in the slopes of the roads, the ascents and the descents. Also, the economic difficulties that prevail make the replacement of old vehicles with new anti-pollution technology (EURO V, VI) quite difficult for Greeks. To answer questions about the readiness of the public to welcome and assimilate ecological driving, this thesis presents a statistical study by using a specially created quiz / questionnaire named "Ecological Driving" and distributed within the prefecture of Rethymno. The questions were mainly about drivers' daily habits as well as questions about gender and the age of the responders. The results of the questionnaire were processed with the IBM SPSS software. Then, in order to locate points within the city that often record delinquent behaviors of ecological driving and therefore create traffic congestion and intense emissions of CO_2, a group of volunteers was created. The volunteers, with their vehicles but also equipped with an OBD unit (On Board Diagnostic, a plug and play tool that helps monitor and record vehicle operating data) performed city trips, during different days of the week and critical hours for the city's freight traffic during the winter months of the year 2019. The data from the OBD devices, were analyzed using the Python programming language and the crucial points that were detected, are illustrated with the use of Tableau software.

The results of the statistical study indicated that the age range 45-64 and 25-44 had the highest ecological driving knowledge / success rate, while the nature of the questions that had the highest failure rates were related to the speed limits, gear change, abrupt braking and acceleration as well as the broader concept of efficient driving. Finally, the depiction of ecological driving violations showed heavy density

of points centrally in the city of Rethymnon and more specifically, in the broader area of the garden, around the general hospital as well as in the coastal area of of the city closed to the urban KTEL. Finally, intense emissions of harmful pollutants were observed in the area of the marina of the city's port and on Sofokli Venizelou Street.

The study highlights the need for decongestion of those points that hinder ecological driving. There is a need for public information about alternative forms of transportation in order to decongest those streets and spots from heavy traffic, about the advantages of ecological driving as well as its promotion. In conclusion, it is proposed to implement the same recording model during the summer period, where an increase of vehicle traffic jams is expected. Then, it is suggested a larger number of volunteers to be equipped with OBD devices as well as the investigation and creation of a model for ecological driving, based on driving habits.

Περίληψη

Ο τομέας των μεταφορών θεωρείται από τους πλέον ρυπογόνους και είναι υπεύθυνος για το 20.5% περίπου των εκπομπών διοξειδίου του άνθρακα (CO_2) παγκοσμίως. Το 25% αυτού του ποσοστού αφορά τις εκπομπές από τις χερσαίες μεταφορές σε παγκόσμια βάση, ενώ το 2016 το 21% του συνολικού ποσοστού παραγωγής CO_2 στην Ευρώπη, οφειλόταν σε αυτές. Η οικολογική οδήγηση συνδέεται άρρηκτα με την εξοικονόμηση καυσίμου, με τη μείωση των εκπομπών επιζήμιων ρύπων αλλά και με την οδική ασφάλεια κατά τις χερσαίες μεταφορές. Οι παράγοντες που μπορούν να επηρεάσουν την οικολογική οδήγηση είναι αρκετοί και θα πρέπει να τους δοθεί η απαραίτητη σημασία και να υπάρξει η κατάλληλη ενημέρωση προς τους οδηγούς. Στη Ελλάδα, και συγκεκριμένα στην Κρήτη, η οικονομική και φιλοπεριβαλλοντική οδήγηση, μπορεί να θεωρηθεί αρκετά δύσκολή λόγω του βραχώδους ανάγλυφου του νησιού, με τις συνεχείς αυξομειώσεις στις κλίσεις των δρόμων, τις αναβάσεις και τις καταβάσεις. Επιπλέον, οι οικονομικές δυσκολίες που επικρατούν, καθιστούν την αντικατάσταση των παλαιών οχημάτων με νέα αντιρρυπαντικής τεχνολογίας (EURO V,VI) αρκετά δύσκολη για τους Έλληνες. Προκειμένου να απαντηθούν ερωτήματα σχετικά με την ετοιμότητα του κοινού να υποδεχθεί και να αφομοιώσει τον τρόπο λειτουργίας της οικολογικής οδήγησης, η μελέτη αυτή παρουσιάζει μια στατιστική μελέτη με τη δημιουργία ερωτηματολογίου «Οικολογικής Οδήγησης» και το διαμοιρασμό του εντός του νομού Ρεθύμνης. Οι ερωτήσεις αφορούσαν κυρίως καθημερινές συνήθειες των οδηγών καθώς επίσης και ερωτήσεις φύλου και ηλικίας. Τα αποτελέσματα του ερωτηματολογίου επεξεργάστηκαν με το λογισμικό IBM SPSS STATISTICS V.25. Στη συνέχεια, προκειμένου να εντοπιστούν σημεία εντός πόλεως που καταγράφονται συχνά παραβατικές συμπεριφορές της οικολογικής οδήγησης και συνεπώς δημιουργείται κυκλοφοριακή συμφόρηση αλλά και έντονες εκπομπές επιζήμιων ρύπων, δημιουργήθηκε ομάδα εθελοντών με σκοπό τον εντοπισμό των σημείων αυτών. Οι εθελοντές, με τα επιβατικά τους οχήματα αλλά και εξοπλισμένοι με μονάδα On Board Diagnostic (OBD), εργαλείο plug and play που βοηθάει στη παρακολούθηση και καταγραφή στοιχείων λειτουργίας των οχημάτων) εκτέλεσαν διαδρομές εντός της πόλης, διαφορετικές ημέρες της εβδομάδας και κρίσιμες ώρες για τον κυκλοφοριακό φόρτο της πόλης, τους χειμερινούς μήνες του έτους 2019. Η ανάλυση των δεδομένων από τα μηχανήματα έγινε με τη γλώσσα προγραμματισμού

Python και τα κρίσιμα σημεία που εντοπίστηκαν, απεικονίζονται με το λογισμικό Tableau.

Τα αποτελέσματα της στατιστικής μελέτης έδειξαν ότι το ηλικιακό εύρος 45-64 και 25-44 είχε το μεγαλύτερο ποσοστό επιτυχίας/γνώσης οικολογικής οδήγησης, ενώ η φύση των ερωτήσεων που είχαν τα μεγαλύτερα ποσοστά αποτυχίας σχετίζεται με τα όρια ταχύτητας, την αλλαγή ταχύτητας, το απότομο φρενάρισμα και την επιτάχυνση καθώς και με την ευρύτερη έννοια της αποδοτικής οδήγησης.

Τέλος, η απεικόνιση των παραβάσεων οικολογικής οδήγησης έδειξε μια έντονη πυκνότητα σημείων κεντρικά της πόλης του Ρεθύμνου και πιο συγκεκριμένα στην ευρύτερη περιοχή του κήπου, γύρω από το γενικό νοσοκομείο καθώς επίσης και στη παραλιακή περιοχή του Ρεθύμνου από την πλευρά του αστικού ΚΤΕΛ. Τέλος, έντονες εκπομπές επιζήμιων ρύπων παρατηρούνται στην περιοχή της μαρίνας του λιμανιού της πόλης και περί της οδού Σοφοκλή Βενιζέλου. Η μελέτη επισημαίνει την ανάγκη αποσυμφόρησης εκείνων των σημείων που παρεμποδίζουν την οικολογική οδήγηση καθώς και άλλων παρόμοιων σημείων με όμοια χαρακτηριστικά, τη συνέχιση της ενημέρωσης των πολιτών σχετικά με τις εναλλακτικές μορφές μετακίνησης για την αποσυμφόρηση κυριών κεντρικών σημείων από έντονο κυκλοφοριακό φόρτο, την ενημέρωση των πολιτών σχετικά με τα πλεονεκτήματα της οικολογικής οδήγησης καθώς και την προώθηση της. Εν κατακλείδι, προτείνεται η συνέχιση εφαρμογής του ίδιου μοντέλου καταγραφής και την καλοκαιρινή περίοδο όπου αναμένεται αύξηση της κυκλοφορίας των οχημάτων, συμμετοχή μεγαλύτερου αριθμού εθελοντών καθώς και η διερεύνηση και δημιουργία μοντέλου πρόβλεψης οικολογικής οδήγησης, βάση των οδηγικών συνηθειών.

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OBD: On-board diagnostic

COP21: Paris climate conference

UNFCCC: United Nations Framework Convention on Climate Change

Chapter 1. Introduction

At a time when environmental issues are soaring, governments around the world are called upon to enforce upright and environmentally friendly policies. Citizens' proper observance of laws and understanding of their actions and the impact on the environment can be considered as a social problem.

The transport sector is considered one of the most polluting sectors and accounts for about 20.5% of CO_2 emissions worldwide. More specifically, 25% of this percentage relates to road transport emissions globally, while in 2016, 21% of total CO_2 production in Europe was due to road transport.[1] Especially in Greece, the transport sector is considered a primary reason for air pollution. [2] Across the world and in the European Union, progress has been made towards more sustainable and environmentally friendly mobility. However, it is believed that there are many issues to be improved in order to accelerate the transition to sustainable mobility.

Eco-driving is inextricably linked to fuel saving, reduction of emissions and road safety during road transportation. Many factors can affect eco-driving and they should be given the prime importance and drivers should be adequately informed. Examples of these factors are the continuous speed fluctuations, sudden acceleration and deceleration and failure to select the correct route in advance. The repeated occurrence of these actions can lead to higher fuel consumption, higher CO_2 emissions, increased travel time, increased noise production and road accidents.

In Greece, and especially in Crete, economical and environmentally friendly driving can be considered quite tricky due to the rocky terrain of the island, with steady increases in road gradients, ascents and descents. Besides, the current financial difficulties make the replacement of old vehicles with new ones that incorporate anti-pollution technologies (EURO V, VI) quite tricky for Greeks, with the average age of cars on the roads being about 15 years old.[3] The existing situation can be improved with possible changes and interventions on the road and beyond.

Considering the above factors, the implementation of direct eco-friendly driving practices with no additional cost to drivers can be regarded as necessary. To do so, it is dictated to record the readiness of citizens to implement eco-driving principles, identify different groups of ages, gender, or issues that make the implementation of eco-driving difficult. Finally, to make it easier for the drivers to use eco-driving principles, streets and spots inside the cities that make their usage difficult must be located.

The diploma thesis comprises two different sections. The first section involves the distribution of questionnaires related to eco-driving manners and the statistical analysis of the responses. The scope of this section is to i. understand public awareness about eco-driving ii. understand if there is appropriate ground and maturity of the public to implement eco-driving iii. identify potential groups that do not use eco-driving or do not have sufficient knowledge of the subject iv. Identify factors that make the implementation of eco-driving difficult and v. inform the public about the benefits of eco-driving. The second section involves the creation of a database related to drivers' behavior by measuring CO_2 emissions and other vehicle traffic parameters. The scope of this section is by analyzing the data of the measurements, to i. understand the contribution of eco-driving practices to fuel-saving and the reduction of emissions related to combustion engines ii. categorize the factors that influence eco-driving based on their contribution to increased fuel consumption and therefore to increased emissions iii. locate spots in the city of Rethymno that could make the implementation of eco-driving difficult iv.locate places in the city of Rethymno with high levels of CO_2 concentrations due to vehicles' operation.

Chapter 2. State-of-the-art

Worldwide increase in energy consumption, fossil fuel depletion and CO_2 emissions made many countries take action against global warming and energy saving. Also, at the Paris climate conference (COP21) in December 2015, parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future.[4] The Paris Agreement central objective is to strengthen the global response to the threat of climate change by limiting global warming to well below 2°C above pre-industrial levels and pursuing efforts to limit it even further to 1.5°C. To reach the targets of the Paris Agreement, greenhouse gases have to be reduced significantly. A significant sector regarding CO_2 emissions is the transport sector, which is responsible for nearly 27% of EU-28 greenhouse gas emissions. A part of those emissions, 75% are emitted from road transport.[5]

Many efforts and measures have been adopted to reduce emissions from the road transport sector and improve fuel efficiency and economy. The introduction of automotive standards (e.g., EURO 6/VI) and more efficient engines are some recent examples of efforts to reduce significant amounts of emissions. The introduction of electric vehicles and motors can be considered as one of the most various initiatives with the combination of hybrid cars and engines. Improve fuel quality and renewable fuels (bio-fuels and higher octane fuels) are some other adopted measures. It is estimated that the potential fuel efficiency of advanced engines and technologies could be 4-10% and 2-8%, respectively [6]. 22.70 million cars sold in 2018 and 1.26 million battery electric vehicles around the world. In Greece, the sales of electric vehicles are meager [Hellenic Republic, Ministry of Interior, 06/2018], [7]. On the other hand, adopting eco-driving manners could lead to significant improvement in fuel economy and fuel efficiency can be up to 45%.

Eco-driving, as frequently referred, is the change from an “aggressive” driving style to a more refined one that incorporates many advantages (Table 2.1). The benefits of eco-driving, of course, go beyond CO_2 reductions. They include reducing the cost of driving (to the individual) and producing tangible and well-known safety benefits (with fewer accidents and traffic fatalities). Eco-driving is an initiative that can improve fuel efficiency and reduce road accidents and noise as a result of the drivers' calm driving [8] The main characteristics of eco-driving can be easily recognized and contain:

1. Accelerating moderately (with shift ups between 2,000 and 2,500 RPM engine speed for those with manual transmissions), 2. Anticipating traffic flow and signals, 3. Avoiding sudden starts and stops; 4. Maintaining an even driving pace (using cruise control, when possible, on the highway where appropriate), 5. Driving at or safely below the speed limit; and 6. Eliminating excessive idling. Of course, some automobile maintenance measures should be included, such as maintaining optimum tire pressure and the regular changing of air filters, in their definition of eco-driving.

Table 2.1 Advantages & disadvantages of Eco-driving. [9]

Advantages	Disadvantages
Fuel cost saving	Low public understanding of the nature of eco-driving
Reduction of maintenance and repairing cost	Ingrained driving habits complicating the implementation of eco-driving
Suitable to all cars of any chronology	
Reduction of stress levels	
Greater safety	
Potentially no time loss	
Environmentally and climate-friendly manner of driving	
Noise reduction	

Several studies have focused on eco-driving, its definitions and how it can result to fuel consumption and fuel economy. Among other studies, a significant number focused on the driver's behavior and others on a general factor that could affect the style of driving. Research work identified six classes of eco-driving actions, including driving, trip planning, load management, fuelling, the comfort of the cabin, maintenance. Then, the driving behavior divided into six further categories, accelerating, cruising, decelerating, waiting, driving mode selection and parking [8]. Fuel consumption can be affected by several factors such as travel-related, weather, vehicle model and characteristics, roadway and asphalt conditions, traffic and drivers related factors [6]. As for most research works, eco-driving manners focus on drivers' behavior; there are six major categories that can affect fuel consumption and emissions. These categories are related to driving behaviors or the control a driver has over his vehicle during a journey and includes driving speed, acceleration, declaration, route choice, idling and vehicle accessories [9]. New technology vehicles are equipped with systems that can contribute to the reduction of fuel consumption (e.g., stop-start system, cylinder deactivation, electric/clutched auxiliaries). Conversely, eco-driving comprises some essential tips and factors that can be implemented in everyday life instead of purchasing a new vehicle.

2.1. Major factors of eco driving

a. Driving speed

Eco-driving suggests constant speed for fuel consumption under various road conditions, highways and routes in the city. When possible, cruise control can be activated [10]. In highways where eco-driving is easier to implement, a small reduction of the speed (i.e., from 120 to 110 km/h) could reduce fuel consumption significantly by 12% for diesel cars and 18% for gasoline cars, assuming smooth driving. It must be taken into account that the speed limits of the example can differ from country to country [11]. A study showed that the optimal fuel consumption and emission rates per unit distance were in the range of 60–90 km/h, with considerable increases outside this range [12]. Another report showed that fuel consumption per unit time was in relation to cruising speed and also fuel consumption per unit distance was optimal between 50 and 70 km/h [13]. It must be noted that fuel economy is in relation to cruising speed because each engine has an optimal speed for fuel economy. Fuel consumption of the vehicle decreases when the engine increases speed and then increases at high speed due to the increased friction losses.

Some of the techniques mentioned above are not taking into account real-world conditions. When it comes to a real-world situation, eco-driving speed limits are recommended at or safely below the speed limit.

b. Acceleration & declaration

A part of the concept of eco-driving is to change the aggressive driving style, which mainly refers to hard acceleration and deceleration, to a smoother one. It is calculated that with aggressive driving could be limited fuel economy by 15–30% at highway speed and 10–40% in stop-and-go traffic [10]. Generally, a smooth driving style saves fuel and increases safety compared to aggressive driving. For an ecological driving manner, it is suggested to the drivers to look ahead for road grades, signals and observe the traffic flow. In this way, the usage of hard acceleration and brake pedals is minimized. A research work related to heavy-duty powertrain underlined that hard acceleration was the critical factor in reducing fuel consumption, in a real-life situation. Acceleration was responsible for 70% of the fuel consumption and 60-80% of CO, HC and NOx emissions of the entire cycle, while shared 35% of total driving time. [14]

Assuming driving with a gentle and smoother driving style, a potential roughly acceleration could lead to an increase of fuel consumption by 50% or more, 3% more CO_2 emissions, 20 times more CO, six times more HC, but 65% fewer NOx emissions compared with gentle driving. In any case, increasing speed and deceleration are the key variables that impact fuel economy and outflows [12]. The most prominent fuel economy might be reached when the most aggressive drivers, change their habits and drive with lower acceleration

It was proposed that forceful drivers ought to center on lessening increasing speed, whereas less forceful drivers ought to center on diminishing speed on interstates.

c. Idling

Idling should be minimized because every vehicle achieves zero fuel efficiency (0 km/L) when idling [8]. Idling could be characterized as a bad habit and manner of driving due to the high prices of CO, HC, NOx and PM that can be produced. Idling vehicles can consume 0.6-5.7 L/h of fuel (depending on the vehicle type, engine size, fuel type and load) [9]. Modern cars do not need to idle to warm up the engine even the cold days. The right temperature could be reached faster by driving gently for about 30s [10]. When waiting time is expected to be higher than the 1-minute engine should be turned off and fuel economy could be improved by 19% on a 10-mile route[15]. It must be mentioned that new technologies cars are equipped with a system that helps to avoid idling and thus the increase in fuel consumption.

Furthermore, this technology identifies the inactivity of the vehicle and automatically turns off the engine whenever idling, and restarts comfortably when drivers touch the accelerator pedal [16]. This functionality can be easily recognized during the short stoppages of the vehicles at the traffic lights. Generally, it should be known that the vehicle achieves zero fuel efficiency (0 km/L) when idling.

d. Route choice

Another essential factor that could affect fuel consumption and emissions from vehicles is route choice. More specifically, when drivers consider their destinations and mark the best route (i.e., low traffic zones, hours of the day without traffic jams) before they start to drive, could help the implementation of the aforementioned eco-driving factors and lead to fuel economy, reduced fuel consumption and harmful emissions. There is a significant number of research work developing eco-routing approaches in order to minimize CO_2 emissions and fuel consumption. A developed strategy, which is choosing the path with the minimum amount of CO_2 emissions and by satisfying time constrains, could reach an 11% reduction of harmful emissions when the travel time buffer was around 10% [13]. Another model calculated the fuel consumption for routes with different times to reach the destination, underlined the potential reduction to fuel consumption over the fastest road method (25%) and shortest route method (23%) [14]. Road type and grade could influence fuel economy and emissions, but the road type determines the speed, acceleration and deceleration profiles also. Fuel economy could be 9% better on highways with an 80 km/h speed limit or higher than other roads.

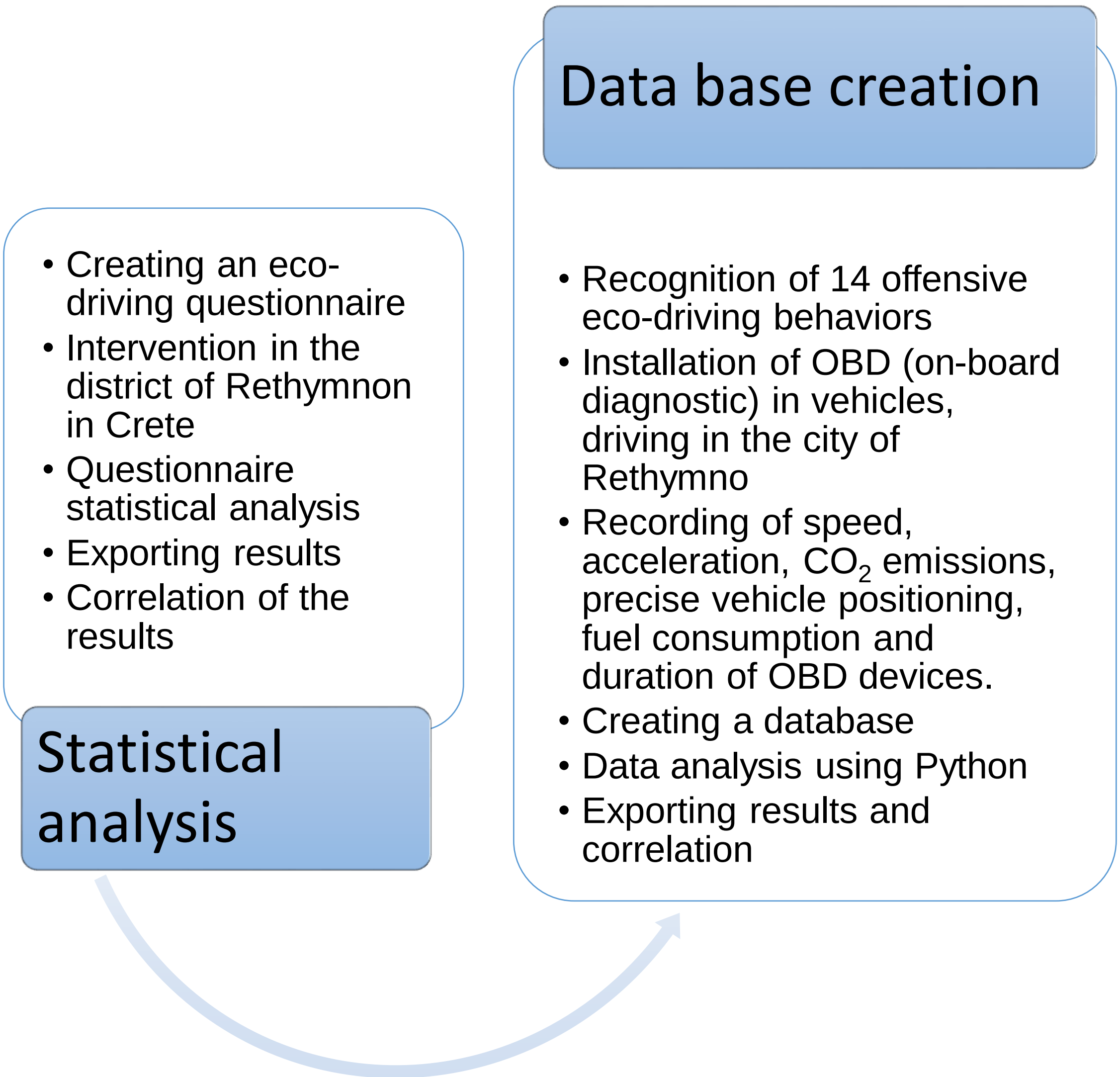
Route choice is likely to reduce travel distance but not necessarily time travel[15]. However, a report explained that a possible increased number of eco-drivers could lead to adverse effects on global emissions due to the increased congestion [16].

e. Other factors

Eco-driving is not always about driving manners but includes other factors that can affect fuel economy and the limitation of emissions. Air conditioning system is not efficient at low speed on city streets because of the usage of extra fuel. Instead, natural ventilation and cooling could be more effective at low speeds and in highways air conditioning if it is not operating at maximum load [21]. In the same way, extra weight should be avoided. 45 kg of extra weight can increase fuel consumption by 1–2% while fuel consumption could be increased by 1–2% by driving with under-inflated tires [8].

Chapter 3. Methodology

The expected methodology about testing the knowledge of the citizens of Rethymno city about eco-driving and the capability of young drivers to implement eco-driving principles is described below. Furthermore, the basic knowledge of the citizens is tested by using a survey/questionnaire. In contrast, the real life behavior of young drivers is tested by mounting an OBD device on their vehicle and by monitoring their driving skills. (Graph 3.1)



Graph 3.1 Methodology in the aggregate

3.1. Survey on the capability of the citizens about eco-driving knowledge

The study targeted in answering a series of questions related to ecological driving and its implementation. We assumed that a questionnaire focused on everyday life practices of driving and driving manners/tips could lead to the exploration of how easy could be the implementation of eco-driving by the residents of Crete. Furthermore, a few questions about the air pollution caused by vehicle operation could lead to the understanding of driving manners from the drivers themselves and relate these manners with demographic data such as age, gender, their permanent residency and the vehicle they drive. The questionnaire was structured in such a way to avoid any misunderstandings and the process was implemented in two stages as it is described below. (Annex). More specifically, the questions were formulated in such a way so, the next goals to be fulfilled:

1. Understanding public awareness of ecological driving
2. Understanding whether there is appropriate ground and maturity for the public to implement eco-driving.
3. Identifying potential groups that do not use eco-driving or do not have sufficient knowledge of the subject.
4. Identifying factors that make the implementation of eco-driving difficult.
5. Informing the public about the benefits of eco-driving.

The study took place in the city of Rethymno in Crete during the summertime of the year 2019 and it was conducted in two stages. The first stage involved the completion of the quiz/questionnaire by citizens, with the help and supervision of Renewable and Sustainable Energy laboratory staff. The second included the distribution of the correct answers of the survey and the correction of the already completed quiz. The purpose of this immediate correction was to map out the weaknesses of respondents and highlight their mistakes as future practical pieces of advice. It should be mentioned that the distribution of the questionnaires took place during some of the actions of the Renewable and Sustainable Energy Laboratory for European mobility week. After the completion and correction of the survey, drivers were given a promotional gift to determine the energy class of their vehicle [22,23].

The study was implemented with the aid of a structured questionnaire. [24], [25], [26] It included mainly closed-ended questions (True-False), ranking, multiple-choice and specified-answer questions). [27] The collected data were analyzed statistically using IBM SPSS STATISTICS V.25 [28,29,30,31]. Specifically, the questionnaire was distributed, through random sampling, to citizens of the city of Rethymno. The sample consisted of 74 citizens who voluntarily participated in the survey. In order for the results to be more easily assessed, the questionnaire was structured in accordance to the different subjects related to basic knowledge of car operation and eco-driving implementation (economic driving, air pollution, noise during operation, short or a long stop of vehicle etc.), as conceptualized in our study.

More precisely, the first section contained questions about the maintenance of the vehicle and more specifically the tires of the car (years of change, increased vehicle performance by larger tires); the second section asked questions related to full or short time stops of the cars and how this can affect the fuel consumption; the third part was related to the windows of the car and how can affect the fuel consumption if they open or close; the fourth section referred to cargo transport with the vehicle and the increase of fuel consumption; the fifth one referred to ecological driving and its implementation; while the sixth and seventh sections were dealt with air pollution and noise increase due to vehicle operation; the eighth section included some general questions about vehicle operation and the final section included question referred to - demographics (gender, age, residential area and type of vehicle for daily transportation).

In our statistical analysis, percentages (of occurrences) were mainly used for the categorical or dichotomy variables. Also, for the examination of a possible relation (independence) between two categorical variables, the chi-square test was used (with a level of significance a=0.05).[32] The findings of our statistical analysis are presented below, grouped into two categories: (i) descriptive statistics/information for each one of the questions/variables in the questionnaire. Frequency tables, graphs and statistical measures per variable were used to present the findings. (ii) statistically significant (cor)relations of variables (by means of double-entry / contingency tables and the use of the chi-square statistic) in order to explore how driving factors could relate to driver's implementation of eco-driving and possible groups of people that are difficult to implement eco-driving.

3.2. Young Drivers real-life behavior test

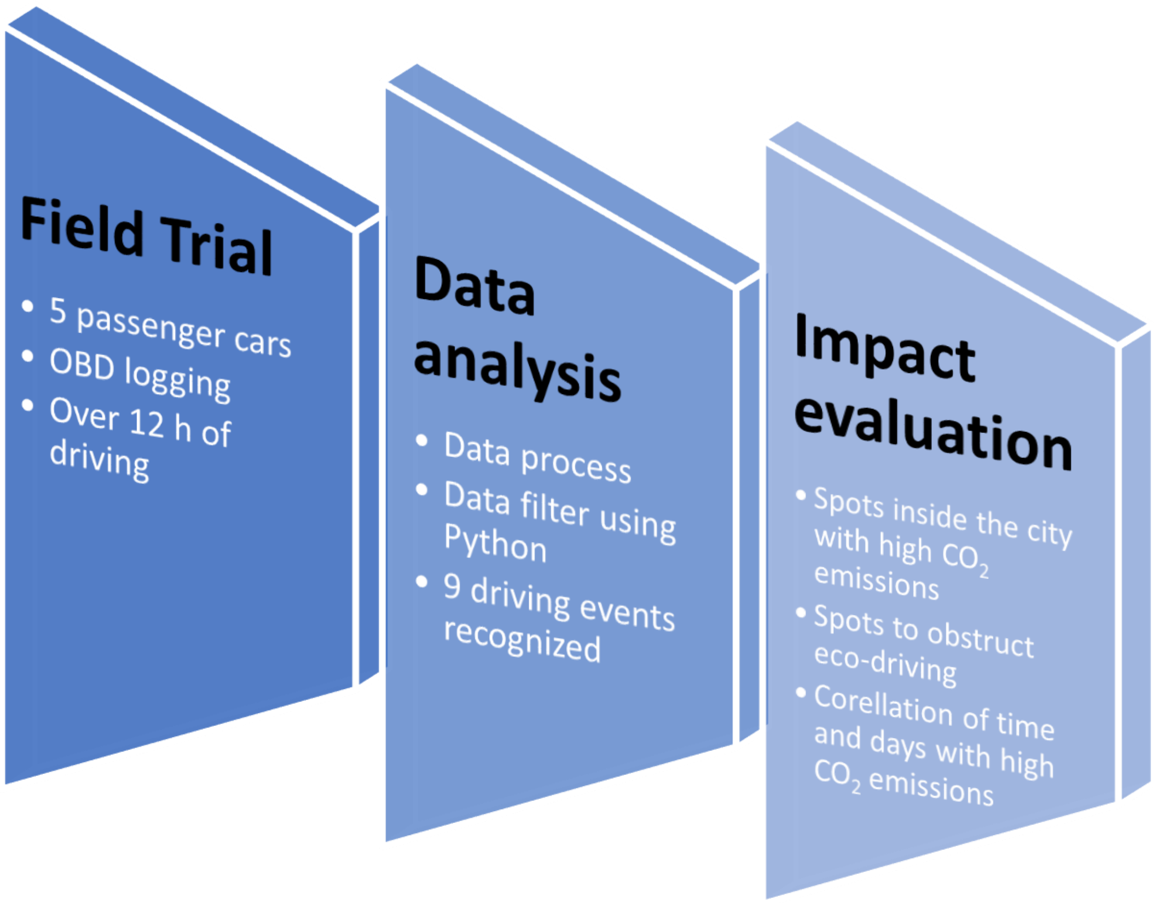
3.2.1. Vehicle CO_2 emissions and Operating data collection

In this study, the operating data and CO_2 emissions of five passenger cars were collected in 3 months through an on-board diagnostic (OBD) device mounted on vehicles in the city of Rethymno Crete, in Greece. Collected data included time, vehicle's location information (longitude and latitude), speed (km/h & m/s), engine speed (rounds per minute, RPM), engine torque (N·m), travel distance (km) and vehicle CO_2 emissions instantaneous (g/km).[33] Two out of five cars had petrol engines, one had a diesel engine and one car was running with a liquefied natural gas engine. Vehicles' fuel consumption was certified by the National Level III and IV emission standards. The operation period for the vehicles was November and December of 2019 and February of 2020. The amount of collected data was over 43,000 records per second and the total driving time was nearly 12 h. (Table 3.1,3.2 & Graph 3.2)

Table 3.1 On-board data collection details

Location	Rethymno Crete (inside the city)
Collected days	Monday to Sunday
Collected hours (records)	9:30-10:30 (8263) & 14:30-16:30 (13050) &17:30-19:30 (6231) & 21:30-22:00 (15456)
Operating period	November-December 2019 & February 2020
Vehicles' type	Passenger cars
Drivers group of age	18-24

After the investigation of the results of the survey on the capability of the citizens about eco-driving knowledge, it was decided to test the young drivers' real-life driving behavior. The ages 18-24 gained the lowest success rate of the survey among the others.



Graph 3.2 On-board data collection methodology

3.2.2. Vehicle Fuel Consumption and Operating Data Collection

This study concerns only with the evaluation of drivers' behavior under normal circumstances and inside the city routes. In this way, some of the data collected were not taken into account:

- Speed > 60 km/h. The vehicles used in this paper operated on an urban road, with a speed limit of 50 km/h, except for particular points and roads which stated by traffic signs [33,34]. Thus, data with vehicle speed over 60 km/h are ignored.

- Absolute Value of Acceleration > 20 km/h/s. Data with vehicle acceleration more than 20 km/h/s and lower than −20 km/h/s are judged beyond the engine's physical capabilities and ignored [33,35,36].

- Missing values for more than two consecutive s is considered to interrupt a driving event due to the operation of the OBD and the collection of data every s. Thus, after two consecutive missing prices, it starts a new driving event.

3.2.3. Defining driving events

Nine typical driving events were recognized and used to assess the driving behavior inside the city of Rethymno and to spot road parts where the implementation of eco-driving is difficult and CO_2 emissions due to these events are high. These spots are recognized due to the drivers repeatedly non-eco driving behavior. The nine events of driving behavior include Accelerating Sharply (AS), Decelerating Sharply (DS), Long-Time Accelerating (LA), Long-Time Idling (LI), Running with Low Speed (LS), Cruising with Higher Speed (HS), Starting Moderately (SM), Frequently Stop and Start (SS), Braking Moderately (BM). The definition of every event is listed below. Here, $a(t)$ is the acceleration at time t s, km/h/s, Ta is accelerating duration time, s, Ti is decelerating duration time, s, $s(t)$ speed at the time t s, km/h, ave, std, abs, max, and min are calculating the average, standard deviation, maximum price, and minimum price of given arguments/measurements. [33,37,38,39]

- AS (Accelerating Sharply): a(t) > 4 km/h/s. A period with continuous instantaneous ASs is identified as an AS event.
- DS (Decelerating Sharply): a(t) < 5 km/h/s. A period with continuous instantaneous DS is identified as a DS event.
- LA (Long-Time Accelerating): Ta > 5/s. Accelerating that lasts more than 5s is identified as one LA event.
- LI (Long-Time Idling): Ti > 60/s. Idling that lasts more than 60s is identified as one LI event.

- LS (Running with Low Speed). Average speed during 60 s is no more than 23 km/h (see (2)), and a period with continuous LSs is identified as one LS event.

$$\boldsymbol{ave\,(s\,(t)\,,\quad s(t\,-\,1)\,,\ldots,s\,(t\,-\,59))\,\leq\,23km/h}$$

- HS (Cruising with Higher Speed). When driving, during 5 s, one has the following:
  I. Average speed is no less than 60 km/h;
  II. Instantaneous acceleration is no more than 1 km/h;
  III. Speed standard deviation is no more than 1.5 km/h;
  IV. Speed variation is no more than 1 km/h;
  V. A period with continuous HS is identified as one HS event.

$$\boldsymbol{ave\,(s\,(t)\,,s\,(t\,-\,1)\,,s\,(t\,-\,2)\,,s\,(t\,-\,3)\,,s\,(t\,-\,4))\,\geq\,60km/h}$$

$$\boldsymbol{max\,(a\,(t)\,,a\,(t\,-\,1)\,,a\,(t\,-\,2)\,,a\,(t\,-\,3)\,,a\,(t\,-\,4))\,\leq\,1km/h/s}$$

$$\boldsymbol{std\,(s\,(t)\,,s\,(t\,-\,1)\,,s\,(t\,-\,2)\,,s\,(t\,-\,3)\,,s\,(t\,-\,4))\,\leq\,1.5km/h}$$

$$\boldsymbol{abs\,(s\,(t)\,-\,s(t\,-\,4))\,\leq\,1km/h.}$$

- SM (Starting Moderately). When the vehicle accelerates from idling, during 5 s, one has the following:
  I. Speed variation ∈ [10, 20] km/h/s;
  II. Maximum acceleration is no more than 4 km/h/s;
  III. A period with continuous SM is identified as one SM event.

$$\boldsymbol{10km/h\,\leq\,s(t)\,-\,s(t\,-\,4)\,\leq\,20km/h}$$

$$\boldsymbol{max\,(a\,(t)\,,a\,(t\,-\,1)\,,a\,(t\,-\,2)\,,a\,(t\,-\,3)\,,a\,(t\,-\,4))\,\leq\,4km/h/s.}$$

- SS (Frequently Stop and Start). A vehicle idles within 3 s after starting from an idling. A period with continuous SS is identified as one SS event.
- BM (Braking Moderately). When decelerating, during 5 s, one has the following:
  I. Deceleration ∈ [−25, −15] km/h/s;
  II. Minimum acceleration is no less than −5 km/h;
  III. A period with continuous BM is identified as one BM event.

$$\boldsymbol{-\,25\,km/h/s\,\leq\,s(t)\,-\,s(t\,-\,4)\,\leq\,-15km/h/s}$$

$$\boldsymbol{min\,(a\,(t)\,,a\,(t\,-\,1)\,,a\,(t\,-\,2)\,,a\,(t\,-\,3)\,,a\,(t\,-\,4))\,\geq\,-5km/h}$$

Figure 3.1 On-board data collection process of implementation

3.2.4. Data Analysis

Data collected from OBD were extracted in CSV format and were analyzed using Python software. The script was created from scratch using several libraries in Python, such as Pandas and NumPy and working mainly on the Jupyter Notebook environment. The idea was to create a script that by reading big CSV files and processing their prices, would identify all non-eco-friendly events mentioned above and would present specific parameters of them, such as their longitude and latitude, velocity and acceleration in order this data to be plotted afterward. Python was selected due to the significant processing speed of the data, a fact that makes this programming language excellent for big data analysis. A sample of the script code describing the nine eco-driving events can be observed in Figures 3.2,3.3 & 3.4 below.

```
File  Edit  View  Insert  Cell  Kernel  Widgets  Help                    Trusted  | Python 3 O

In [ ]: import pandas as pd
        import numpy as np

In [ ]: data = pd.read_csv("m1.csv")
        data.columns = data.columns.str.strip()

In [ ]: data.rename(columns={'Speed (GPS)(km/h)': 'Speed'}, inplace=True)

In [ ]: Accelerating = data[(data["a(km/h/s)"] > 4)]

        A1 = Accelerating.loc[:,"Longitude"]
        A2 = Accelerating.loc[:,"Latitude"]
        A3 = Accelerating.loc[:,"CO₂ in g/km (Instantaneous)(g/km)"]
        print(A1.to_string(index=False))

In [ ]: print(A2.to_string(index=False))

In [ ]: print(A3.to_string(index=False))

In [ ]: Decelerating = data[(data["a(km/h/s)"] < -5)]
        D1 = Decelerating.loc[:,"Longitude"]
        D2 = Decelerating.loc[:,"Latitude"]
        D3 = Decelerating.loc[:,"CO₂ in g/km (Instantaneous)(g/km)"]
        print("L",D1.to_string(index=False),'\n',"LA", D2.to_string(index=False),'\n',"CO2", D3.to_string(index=False))

In [ ]: #Running with Low speed
        data['Average_Speed'] = data['Speed'].rolling(window=60,center=False).mean()
        LS = data[(data["Average_Speed"] <= 23) & (data["Average_Speed"] >10)]
        LS1 = LS.loc[:,"Longitude"]
        LS2 = LS.loc[:,"Latitude"]
        LS3 = LS.loc[:948,"CO₂ in g/km (Instantaneous)(g/km)"]
        pd.set_option('display.max_rows', 999)
        pd.set_option('precision', 5)
        l = list(LS.index)

        for i in l:
            for y in range(59,1,-1):
                print(data.Longitude[i+y])

In [ ]: for i in l:
            for y in range(59,1,-1):
                print(data.Latitude[i+y])
```

Figure 3.2 Sample of Python script for analyzing eco-driving events

```
In [ ]: for i in l:
            for y in range(59,1,-1):
                print(data["CO₂ in g/km (Instantaneous)(g/km)"][i+y])
```

```
In [ ]: #Cruising with Higher Speed
        data['HS_SPEED'] = data['Speed'].rolling(window=5,center=False).mean()
        data['HS_ACC'] = data['a(km/h/s)'].rolling(window=5,center=False).max()
        data['HS_SPEED_STD'] = data['Speed'].rolling(window=5,center=False).std()
        data['HS_VAR'] = data['Speed'].rolling(window=5,center=False).var()
        HS = data[(data["HS_SPEED"] >= 60) & (data["HS_ACC"] <= 1) & (data["HS_SPEED_STD"] <= 1.5) & (data["HS_VAR"] <= 1)]
        #HS_INDEX = HS.index
        #list(HS.index)
        HS2 = HS.loc[:,"Longitude"]
        HS1 = HS.loc[:,"Latitude"]
        HS3 = HS.loc[:,"CO₂ in g/km (Instantaneous)(g/km)"]
        #HS1
        #HS2
        #HS3
        #list(HS.index-4,HS.index-3,HS.index-2,HS.index-1,HS.index)
        l2 = list(HS.index)
        print(HS.index)
        # tO GET MANUALLY FROM EXCEL BEACAUSE DATASET STARTS FROM 2
        #df["New_Longitude"].append(HS2,ignore_index = True)
        #df["New_Longitude"]
```

```
In [ ]: for i in l2:
            print(data.Longitude[i-4],'\n',data.Longitude[i-3],'\n',data.Longitude[i-2],'\n',data.Longitude[i-1],'\n',data.Longitude[i])
```

```
In [ ]: for i in l2:
            print(data.Latitude[i-4],'\n',data.Latitude[i-3],'\n',data.Latitude[i-2],'\n',data.Latitude[i-1],'\n',data.Latitude[i])
```

```
In [ ]: for i in l2:
            print(data["CO₂ in g/km (Instantaneous)(g/km)"][i-4],'\n',data["CO₂ in g/km (Instantaneous)(g/km)"][i-3],'\n',data["CO₂ in g
```

```
In [ ]: #Starting Moderately
        SM = data[(data["HS_ACC"] <= 4) & (data["HS_VAR"] <= 20) & (data["HS_VAR"] >= 10)]
        SM2 = SM.loc[:,"Longitude"]
        SM1 = SM.loc[:,"Latitude"]
        SM3 = SM.loc[:,"CO₂ in g/km (Instantaneous)(g/km)"]
        l3 = list(SM.index)
        for i in l3:
            print(data.Longitude[i-4],'\n',data.Longitude[i-3],'\n',data.Longitude[i-2],'\n',data.Longitude[i-1],'\n',data.Longitude[i])
```

```
In [ ]: for i in l3:
            print(data.Latitude[i-4],'\n',data.Latitude[i-3],'\n',data.Latitude[i-2],'\n',data.Latitude[i-1],'\n',data.Latitude[i])
```

Figure 3.3 Sample of Python script for analyzing eco-driving events (2)

```
In [ ]: #Braking Moderately
        data['BM_ACC_MIN'] = data['a(km/h/s)'].rolling(window=5,center=False).min()
        BM = data[(data["BM_ACC_MIN"] >= -5) & (data["a(km/h/s)"] <= -15) & (data["a(km/h/s)"] >= -25)]
        BM2 = BM.loc[:,"Longitude"]
        l4 = list(BM.index)
        for i in l4:
            print(data.Longitude[i-4],'\n',data.Longitude[i-3],'\n',data.Longitude[i-2],'\n',data.Longitude[i-1],'\n',data.Longitude[i])
```

```
In [ ]: for i in l4:
            print(data.Latitude[i-4],'\n',data.Latitude[i-3],'\n',data.Latitude[i-2],'\n',data.Latitude[i-1],'\n',data.Latitude[i])
```

```
In [ ]: for i in l4:
            print(data["CO₂ in g/km (Instantaneous)(g/km)"][i-4],'\n',data["CO₂ in g/km (Instantaneous)(g/km)"][i-3],'\n',data["CO₂ in g
```

```
In [ ]: #Frequently Stop and Start
        data['IDLE'] = data['Speed'].rolling(window=3,center=False).sum()
        SS = data[(data["IDLE"] >= 0) & (data["IDLE"] <= 2)]
        SS2 = SS.loc[:,"Speed"]
        l5 = list(SS.index)

        for i in l5:
            if i>2:
                if data.Speed[i-3] >2:
                    print(data.Longitude[i-2],'\n',data.Longitude[i-1],'\n',data.Longitude[i])
```

```
In [ ]: for i in l5:
            if i>2:
                if data.Speed[i-3] >2:
                    print(data.Latitude[i-2],'\n',data.Latitude[i-1],'\n',data.Latitude[i])
```

```
In [ ]: for i in l5:
            if i>2:
                if data.Speed[i-3] >2:
                    print(data["CO₂ in g/km (Instantaneous)(g/km)"][i-2],'\n',data["CO₂ in g/km (Instantaneous)(g/km)"][i-1],'\n',data["
```

```
In [ ]: for i in range(0,len(data)):
```

Figure 3.4 Sample of Python script for analyzing eco-driving events (3)

3.2.5. Python®[1]

3.2.6. Data visualization [2]

[1] Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. It is high-level built-in data structures, combined with dynamic typing and dynamic binding, makes it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components. Python's simple, easy to learn as the syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms and can be freely distributed. Often, programmers choose to work with Python because of the increased productivity it provides. Since there is no compilation step, the edit-test-debug cycle is incredibly fast. Debugging Python programs is easy; a bug or bad input will never cause a segmentation fault. Instead, when the interpreter discovers an error, it raises an exception. When the program doesn't catch the exception, the interpreter prints a stack trace. A source-level debugger allows inspection of local and global variables, evaluation of arbitrary expressions, setting breakpoints, stepping through the code a line at a time, and so on. The debugger is written in Python itself, testifying to Python's introspective power. On the other hand, often the quickest way to debug a program is to add a few print statements to the source, the fast edit-test-debug cycle makes this simple approach very effective. [40,41,42]

The notebook extends the console-based approach to interactive computing in a qualitatively new direction, providing a web-based application suitable for capturing the whole computation process: developing, documenting, and executing code, as well as communicating the results. The Jupyter notebook combines two components:

- A web application: a browser-based tool for interactive authoring of documents which combine explanatory text, mathematics, computations and their rich media output.

- Notebook documents: a representation of all content visible in the web application, including inputs and outputs of the computations, explanatory text, mathematics, images, and rich media representations of objects.[43]

[2] In order the spots in the city of Rethymno with a high concentration of CO_2 emissions and frequent violations of eco-driving principles to be presented, Tableau Public software selected. Tableau Public is a free service that lets anyone publish interactive data visualizations to the web.[44] This software can be used for the creation of a map or to put data on the map and several types of files can be imported such as CSV or Excel files (Figures B1 & 2).

Chapter 4. Results on the capability of the citizens about eco-driving knowledge

4.1. Statistical analysis

The results of the statistical analysis are grouped below in two sections. The first section provides descriptive information for each one of the questions/variables in the questionnaire by using frequency tables, graphs and statistical measures.

Each frequency table consists of the number of respondents and the relative frequency of each attribute per variable. Two statistical measures used for the variables are the mode (especially for categorical variables) and the median (for ordinal, interval and ratio measured variables). The mode of a variable is its attribute/value with the highest frequency. In contrast, the median of a variable is the value below, in which we have 50% of the measurements of the specific variable. Above that, we have the remaining 50% of the measurements.

The second section examines possible (cor) relations of variables with the help of double-entry / contingency tables and the use of the chi-square statistic.

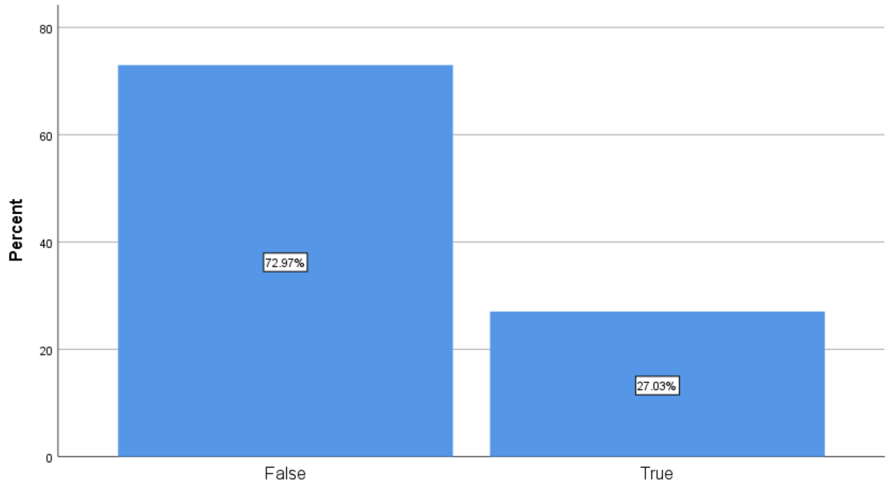
4.1.1. Descriptive statistics

In the first part of the questionnaire/quiz, the responders answered questions related to drive patterns, attendance and maintenance of their vehicles. The results for each variable are listed below and the enumeration here is the same one with the one of the questionnaire.

1. Increased fuel efficiency with bigger tires.

In the first question, responders had to choose if bigger tires can increase fuel efficiency for their vehicles. 72.97% marked the right answer (i.e., that do not increase the fuel efficiency of the vehicles) with “False” and 27.03 % responded “True”. (Graph 4.1)

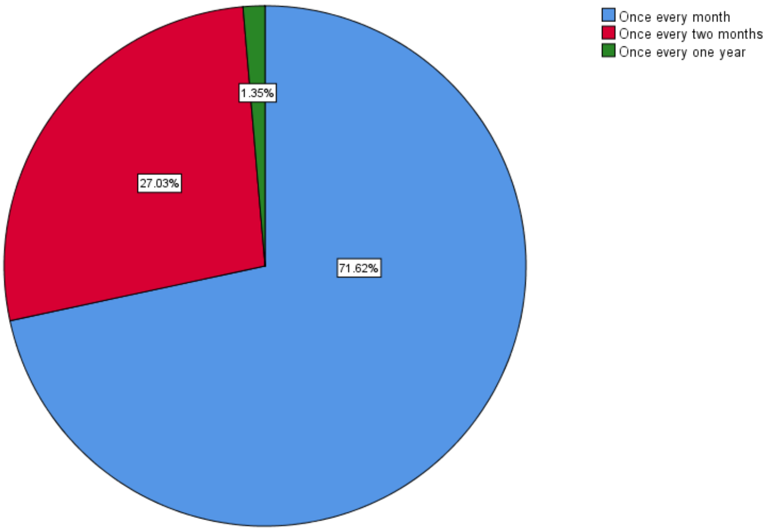
Graph 3.3 Percentages on if “Larger tires can increase fuel efficiency”



2. Frequency of tire pressure checking

As for the frequency of tire pressure checking, responders had to choose between three answers, once in a month, once in every two months and once in a year. The most considerable portion (71.62%) responded with the correct answer “once in a month”, while 27.03% responded with once every two months. (Graph 4.2).

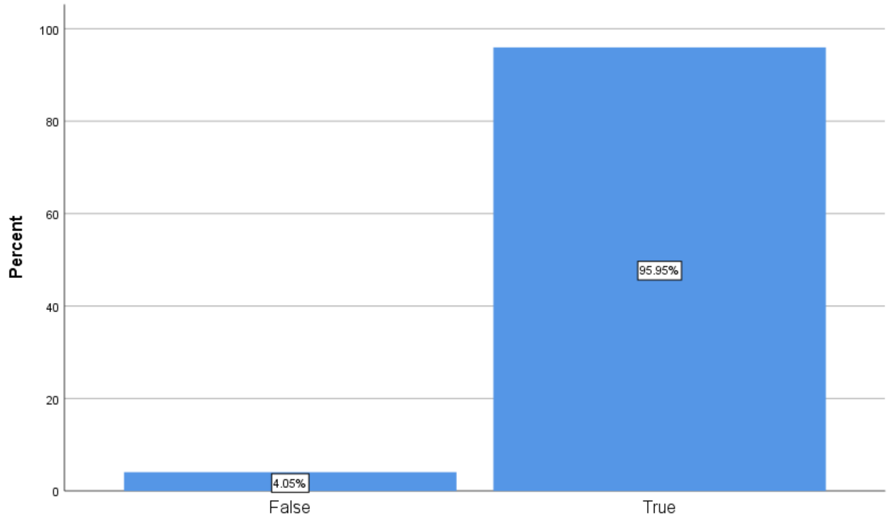
Graph 3.4 Percentages on if "Tire pressure should be checked at least."



3. Short stoppages of vehicles and increase in fuel consumption

The majority of the responders answered correctly (95.95%) to the question if short time stoppages of the vehicles can increase fuel consumption (yes is the correct answer). The rest of the responders (4.05%) answered "False" to this question. We may assume that drivers are well informed about this type of topic. (Graph 4.3).

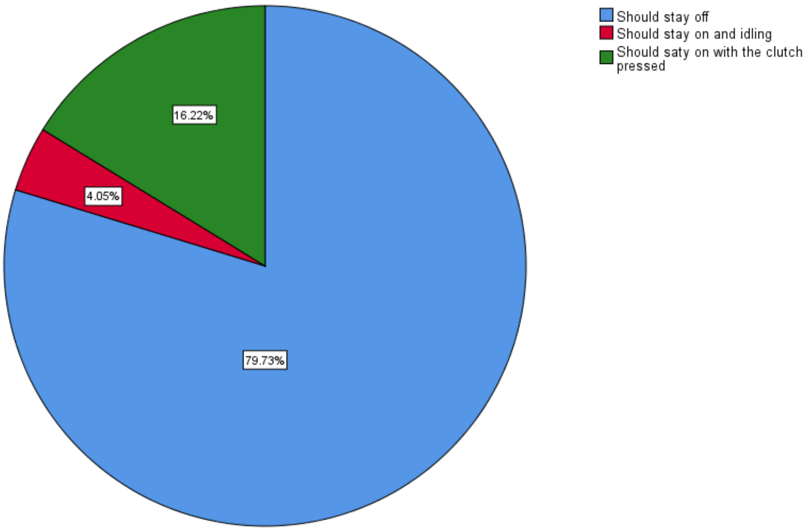
Graph 3.5 Percentages on if "Repeated short stoppages of the vehicle help to increase fuel consumption"



4. Long-time stoppages, shorter than 1 minute

79.73% of the responders knew (correctly) that during a long time stoppages, the vehicle should stay off while 16.22% believed that the vehicle should stay on and idling. 4.05% of the responders answered that the vehicle should stay on, with a gear and the clutch pressed. One single responder did not know what to answer at all. (Graph 4.4)

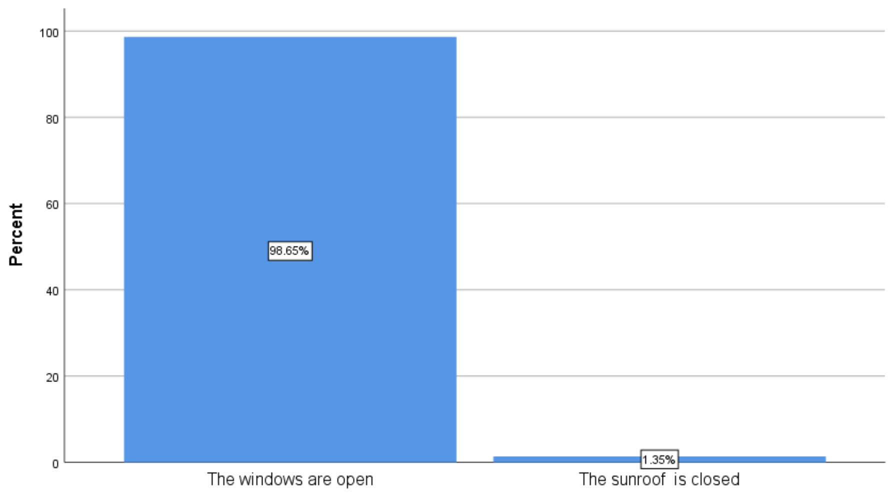
Graph 3.6 Percentages on if "During a full stop, for more than one minute, the vehicle is better"



5. Fuels consumption increase and windows/sunroof

If the windows of a moving car are open, the fuel consumption increases. 98.65% of the responders knew this fact. 1.35% believed that fuel consumption increase when "when the sunroof of the car is closed". (Graph 4.5)

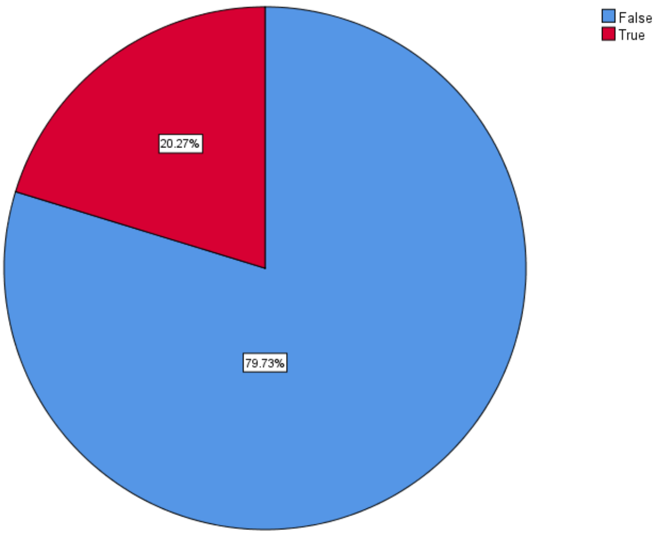
Graph 3.7 Percentages on if "Fuel consumption increases when…"



6. Cargo transfer and fuel consumption

This question was about if “Car’s loads do not affect fuel consumption when the objects are inside the car and not on an external roof rack”. 79.73% of the responders marked the right choice “False” while 20.37% marked the wrong choice “True”. A single responder did not know at all what to answer. (Graph 4.6)

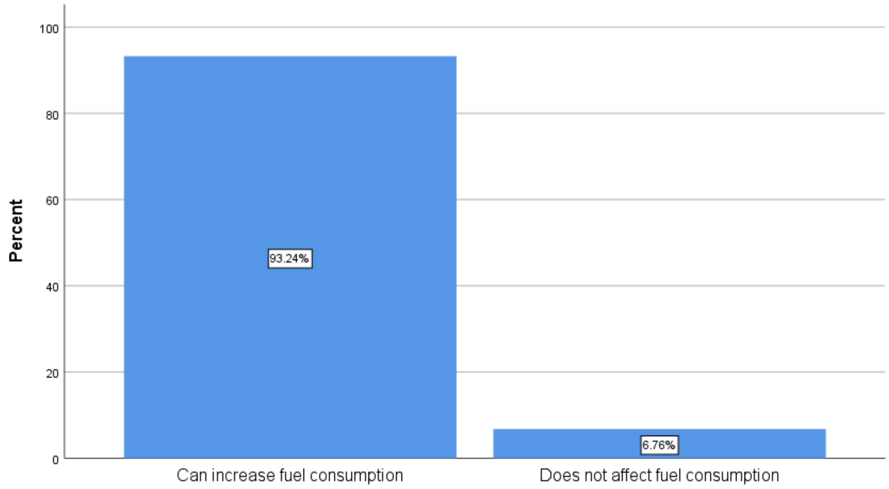
Graph 3.8 Percentages on if “Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack”



7. Driving with roof rack

Driving with a ruff rack, even without carrying cargo, increases fuel consumption. 93.24% of the responders knew that fact, while 6.76% believed that the ruff rack, cannot affect fuel consumption. (Graph 4.7)

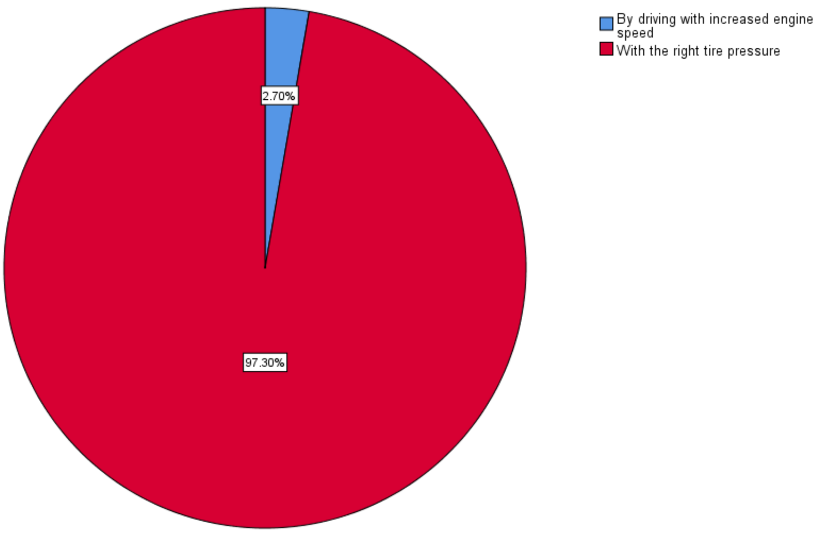
Graph 3.9 Percentages on if "Driving with a roof rack even without any external load"



8. When economic driving could be achieved

Almost all of the responders (97.3%) knew that by the right pressure of the tires, economical driving could be achieved. The rest (2.7%) answered that "driving at increased engine speed" could lead to economical driving. (Graph 4.8)

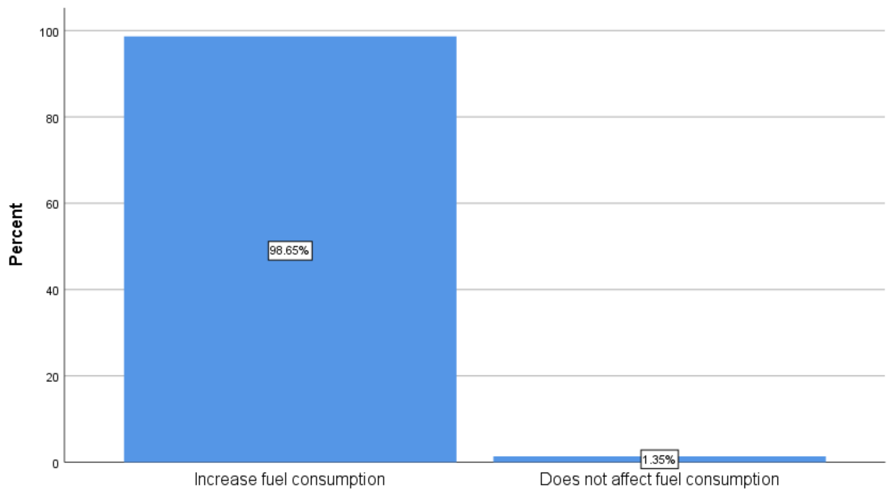
Graph 3.10 Percentages on "Economic driving can be achieved by/with.."



9. Usage of air condition

Almost all of the responders (98.65%) knew that by using air condition, the fuel consumption increases. One responder considered that fuel consumption could not be affected by the usage of air condition. (Graph 4.9)

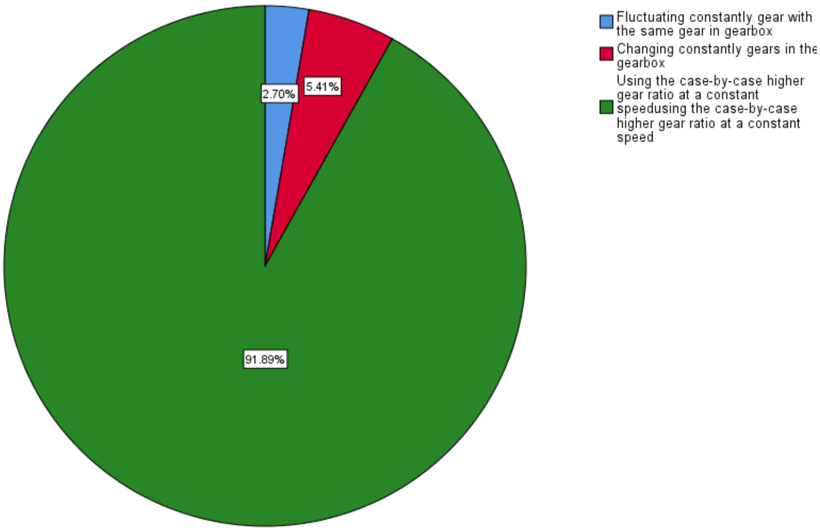
Graph 3.11 Percentages on "The usage of air condition in the car"



10. Economic driving in a road without slope

Most responders (91.89%) knew that by "using the case-by-case higher gear ratio at a constant speed" can achieve economic divining on a road without slope. 5.41% and 2.7% of the responders answered that they should "constantly changing gears in the gearbox" and "constantly fluctuating gear with the same gear in gearbox" would achieve economic driving, respectively. (Graph 4.10)

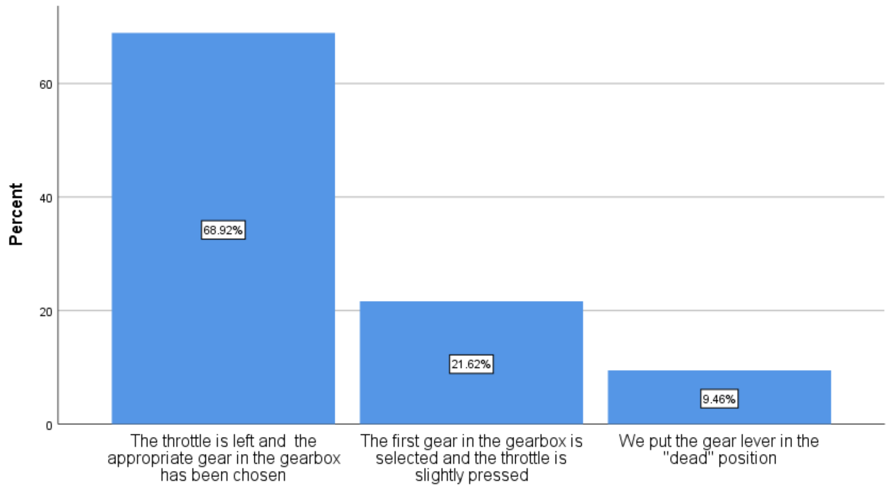
Graph 3.12 Percentages on "Driving on a road without slope, economic driving can be achieved by"



11. Downhill and decrease in fuel consumption

Driving on a downhill, with a new technology car, to decrease fuel consumption, the driver should leave the throttle and choose the appropriate gear in the gearbox. 68.92% of the responders answered correctly on this question. 21.62% of the responders thought that in order to decrease fuel consumption driving on a downhill, they would "put the gear lever in the "dead" position," and 9.46% would "select the first gear in the gearbox and press the throttle slightly". (Graph 4.11)

Graph 3.13 Percentages on "When driving on a downhill with a new technology car, fuel consumption is lower when"



12. The proper number of RPM when changing gear to minimize fuel consumption

The proper number of RPM when changing gear is 2,000-2,500 to avoid increased fuel consumption. 79.7% of the responders answered correctly, while 14.9% answered 1,000-1,500. Only 5.4% marked 3,000-3,500 on this question. (Table 4.1)

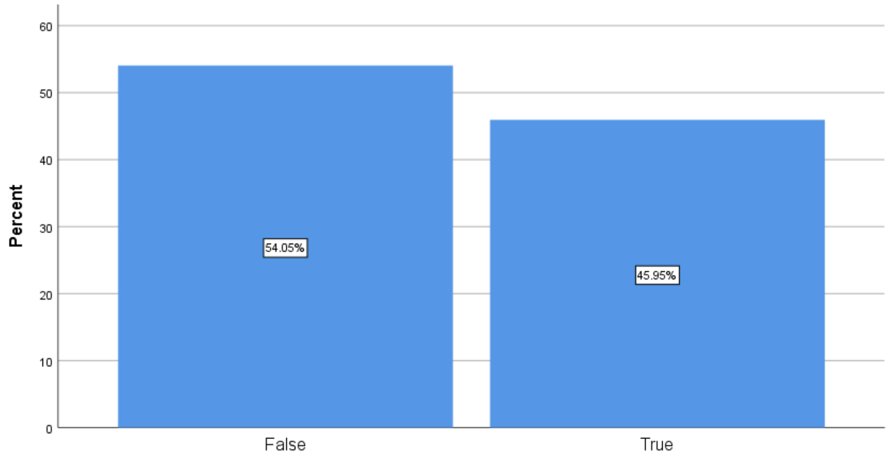
Table 3.2 Percentages on "Which is the proper number of RPM when changing gear, in order the fuel consumption to be minimized"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,000-1,500	11	14.9	14.9	14.9
	2,000-2,500	59	79.7	79.7	94.6
	3,000-3,500	4	5.4	5.4	100.0
	Total	74	100.0	100.0	

13. Fuel consumption and proper gears

"Fuel consumption is more efficient at low speeds". 54.05% of the responders answered "False" in this question, while 45.95% answered "True" as it can be seen from the above Graph 4.12. (Graph 4.12)

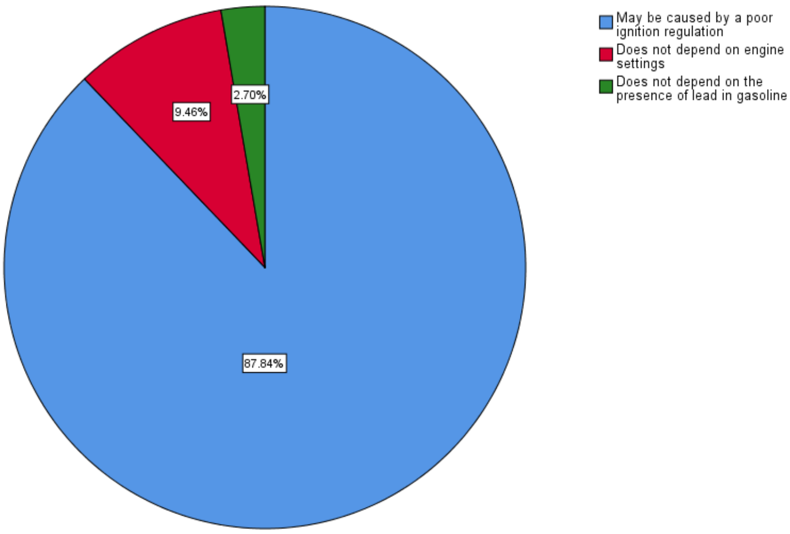
Graph 3.14 Percentages on if "Fuel consumption is more efficient at low speeds"



14. Air pollution by gasoline vehicles

As the responders answered, air pollution by gasoline vehicles, "may be due to poor ignition regulation" (87.84%) and "does not depend on engine settings" (9.46%). 2.70% declared that air pollution from vehicles does not depend on the presence of lead in gasoline. (Graph 4.13)

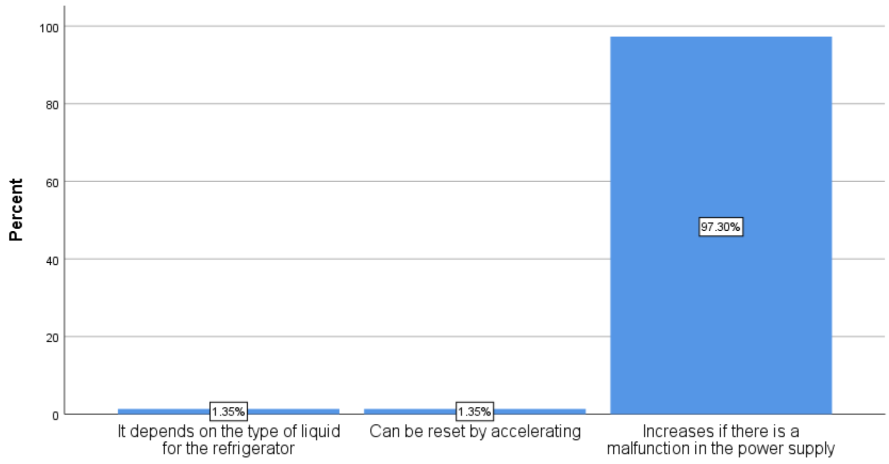
Graph 3.15 Percentages on "Air pollution from gasoline-powered vehicles"



15. Air pollution by diesel vehicles

In this question, 97.3% of the responders answered that air pollution produced from diesel vehicles "increases if there is a malfunction in the power supply". The other two wrong answers, i.e., that the air pollution from diesel vehicles "can be reset by accelerating" and that "depends on the type of liquid for the refrigerator, got, 1.35% of responses each one.

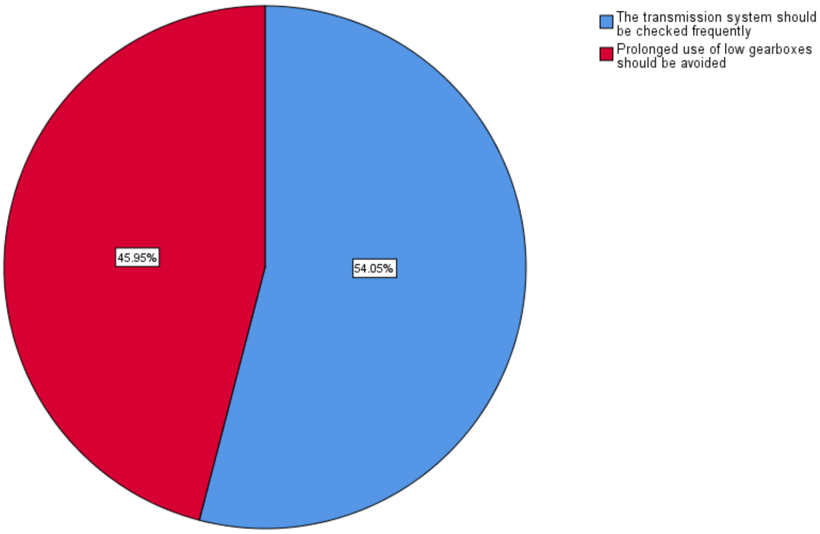
Graph 3.16 Percentages on "Air pollution from diesel engine vehicles"



16. Decrease of air pollution by petrol vehicles

To decrease air pollution from petrol vehicles, the "prolonged use of low gearboxes should be avoided". This was the right answer to the question, and 45.95% of the responders answered adequately. 54.05% answered that "the transmission system should be checked frequently". (Graph 4.15)

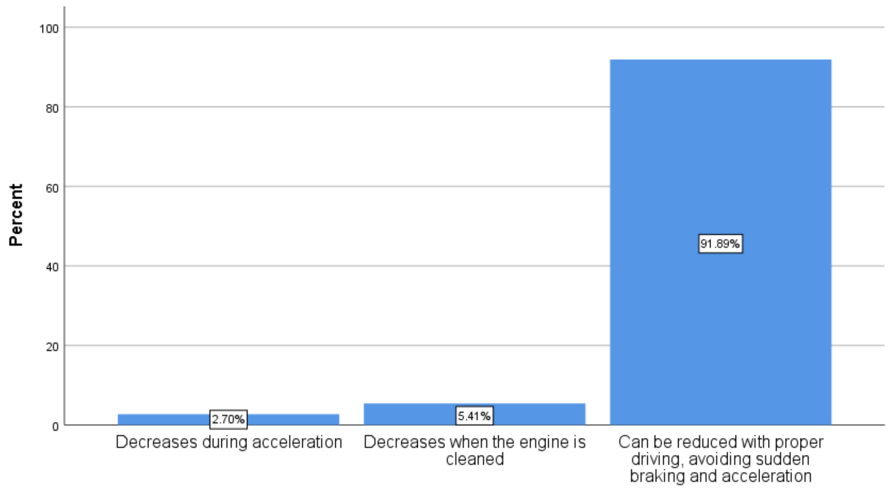
Graph 3.17 Percentages on "Which is the proper action in order to reduce air pollution from petrol vehicles"



17. Noise production from vehicles

The responders of the questionnaire gave the right answer on the question, that the noise from vehicle operation," can be reduced with proper driving, avoiding sudden braking and acceleration" (91.89%) and "decreases if the engine is cleaned" (5.41%). The answer with the lowest percentage (2.70%) referred to the decrease of noise production from vehicle operation during acceleration. (Graph 4.16)

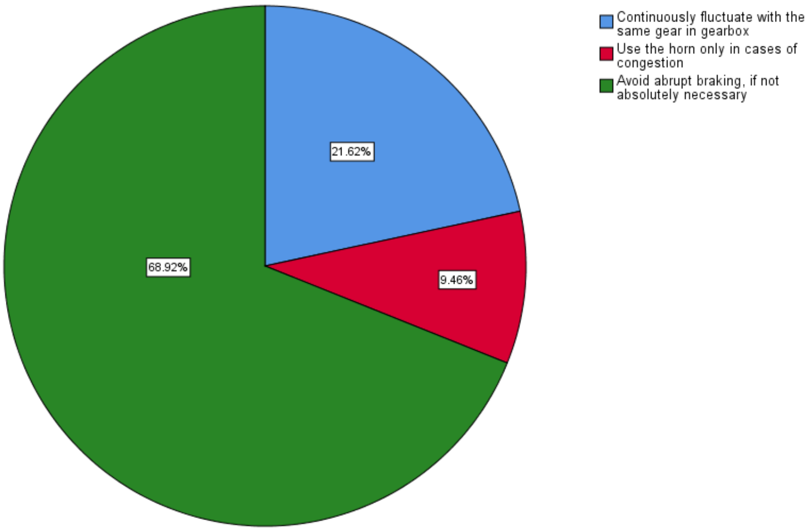
Graph 3.18 Percentages on "Noise production from vehicles"



18. Avoiding noise production during driving

In the question "What is the best action to avoid noise production during driving", the most significant portion of the responders (68.92%) answered the right choice "avoid abrupt braking, if not necessary". The rest responders answered, "use the horn only in cases of congestion" (9.46%) and "continuously fluctuate with the same gear in gearbox" (21.62%) respectively. (Graph 4.17)

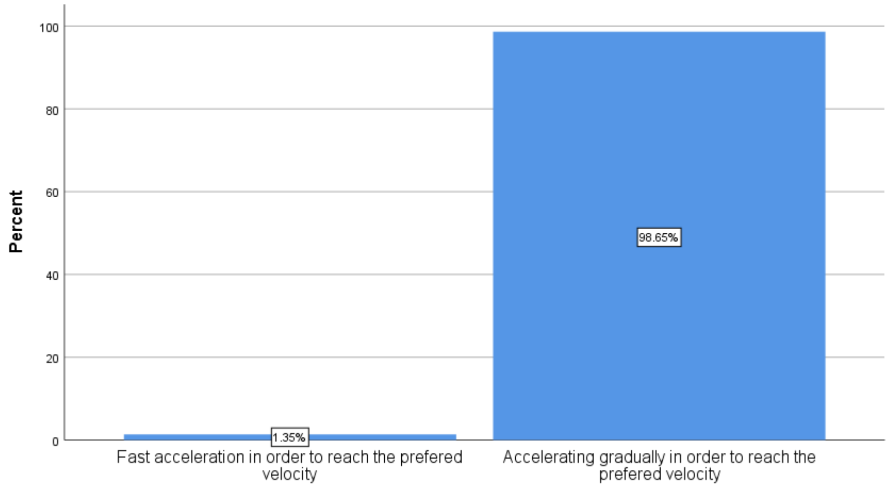
Graph 3.19 Percentages on "Which is the proper action in order to reduce noise production while driving"



19. Proper manners during acceleration

For the question "When accelerating it is better to:" the most considerable portion of the responders (98.65%) chose the answer that is better to gradually accelerate to reach the preferred speed. In comparison, a small portion (1.35%) chose that it is better to accelerate fast to reach the preferred. The majority of the responders is informed that fast acceleration can increase fuel consumption and, thus, air pollution. (Graph 4.18)

Graph 3.20 Percentages on “What is better during acceleration”



20. Fuel consumption and maintenance of the vehicle

In a relevant question, if regular checks by the vehicle’s mechanic can decrease fuel consumption, all the responders answered correctly (100%) “YES”. This fact declares that drivers know that it is a proper action for them to visit a vehicle mechanic frequently.

The second part of the questionnaire collected data such as gender, age, permanent residence and type of vehicle the responders use.

i. Gender

The largest portion of the sample was men (66.2%) in comparison with 33.8%, which were women.

ii. Age

As for the age of the responders, the majority of the sample (40.5%) was between 45 and 64 years and between 25-44 years. (Table 4.2)

Table 3.3 Age distribution of the sample of the survey

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-24	12	16.2	16.2	16.2
	25-44	30	40.5	40.5	56.8
	45-64	30	40.5	40.5	97.3
	>65	2	2.7	2.7	100.0
	Total	74	100.0	100.0	

iii. Permanent residence

The majority of the responders had their permanent residence in the city of Rethymno (70.3%), while the same number of the responders had their residence outside the town and outside the district of Rethymno (14.9%) respectively. (Table 4.3)

Table 3.4 Permanent residence of the sample of the survey

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Inside the city	52	70.3	70.3	70.3
	Outside of the city	11	14.9	14.9	85.1
	Outside of the district of Rethymno	11	14.9	14.9	100.0
	Total	74	100.0	100.0	

iv. Type of vehicle

The primary type of vehicles which the responders drive is car (68.9%), motorcycle (5.4%) and both car and motorcycle (17.6%). A small portion of the responders (4.1%) use public transportation for their needs.

4.1.2. Statistical (cor) relations

To test the possible (cor) relation of two qualitative variables, the chi-square statistical test for independence is used (the greater the confidence, the greater the certainty of their dependence). The SPSS statistical software calculates the chi-square statistic by following the Analyze → Descriptive Statistics → Crosstabs commands and then by selecting in the Statistics window, the chi-square statistic. The resulting table includes the Asymptotic significance value (As. Sig.), denoted by p. If $p > 0.05$ then it means that the two variables are independent and conversely, if $p < 0.05$, the variables are dependent.

Also, the intensity of the relation/relevance of the two variables can be calculated. The coefficients indicating this intensity are Phi and Cramer's V.

a) Gender-Decrease of air pollution by petrol vehicles

There is a statistically significant dependence relationship between the gender of the responder and the answer to the question "Which is the proper action in order to reduce air pollution from petrol vehicles" (answers: it must be avoided the prolonged use of low gearboxes, keep the engine warm by pressing the throttle repeatedly while stopping or by checking the transmission system frequently (x^2=4.896, p-value=0.027, Phi-value= 0.274). (Table 4.4 4.5 & 4.6). The majority of women (72%) think that the proper action is "The transmission system should be checked frequently" in contrast to 55.1% of men who think that the proper action is "Prolonged use of low gearboxes should be avoided". Finally, since Cramer's V is .257, the dependence relation is relatively weak.

Table 3.5 Gender / Which is the proper action in order to reduce air pollution from petrol vehicles Crosstabulation

					Total
			The transmission system should be checked frequently	Prolonged use of low gearboxes should be avoided	
Gender	Male	Count	22	27	49
		% within Gender	44.9%	55.1%	100.0%
	Female	Count	18	7	25
		% within Gender	72.0%	28.0%	100.0%
Total		Count	40	34	74
		% within Gender	54.1%	45.9%	100.0%

Table 3.6 Gender / Which is the proper action in order to reduce air pollution from petrol vehicles Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.896[a]	1	.027		
Continuity Correction[b]	3.865	1	.049		
Likelihood Ratio	5.034	1	.025		
N of Valid Cases	74				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.49.

b. Computed only for a 2x2 table

Table 3.7 Gender / Which is the proper action in order to reduce air pollution from petrol vehicles Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	-.257	.027
	Cramer's V	.257	.027
N of Valid Cases		74	

b) Gender / When driving on a downhill with a new technology car, fuel consumption is lower when

There is a statistically significant difference in the percentages of the right answers to the question, “When driving on a downhill with a new technology car, fuel consumption is lower when:…” (answers: The throttle is left and the appropriate gear in the gearbox has been chosen, the first gear in the gearbox is selected and the throttle is slightly pressed, we put the gear lever in the "dead" position) with respect to the gender of the responders. In this question, 79.6% of males gave the right answer, while 48% of females gave the right answer (p-value=0.00544). (Table 4.7).

Table 3.8 Gender / When driving on a downhill with a new technology car, fuel consumption is lower when, Crosstabulation

			The throttle is left and the appropriate gear in the gearbox has been chosen	The first gear in the gearbox is selected and the throttle is slightly pressed	We put the gear lever in the "dead" position	Total
Gender	Male	Count	39	7	3	49
		% within Gender	79.6%	14.3%	6.1%	100.0%
	Female	Count	12	9	4	25
		% within Gender	48.0%	36.0%	16.0%	100.0%
Total		Count	51	16	7	74
		% within Gender	68.9%	21.6%	9.5%	100.0%

c) Gender - Which is the proper action in order to reduce noise production while driving

There is a significant difference of the percentages of the right answers to the question “Which is the proper action in order to reduce noise production while driving” (answers: Continuously fluctuate with the same gear in gearbox, Use the horn only in cases of congestion, Avoid abrupt braking, if not absolutely necessary) with respect to the gender of the responders. In this question, 75.5% of males gave the right answer, while 56% of females gave the right answer. (Table 4.8).

Table 3.9 Gender / Which is the proper action in order to reduce noise production while driving Crosstabulation

			Continuously fluctuate with the same gear in the gearbox	Use the horn only in cases of congestion	Avoid abrupt braking, if not absolutely necessary	Total
Gender	Male	Count	8	4	37	49
		% within Gender	16.3%	8.2%	75.5%	100.0%
	Female	Count	8	3	14	25
		% within Gender	32.0%	12.0%	56.0%	100.0%
Total		Count	16	7	51	74
		% within Gender	21.6%	9.5%	68.9%	100.0%

d) Age - Larger tires can increase fuel efficiency

There is a significant difference in the percentages of the right answers to the question if "Larger tires can increase fuel efficiency" (answers: True, False) and the age of the responders. In this question, 100% of the group of age >65 gave the right answer (False), while 86.7% of the responders belonging in the group of ages 45-64 gave the right answer. The percentages of success of the other two groups were <65%. (Table 4.9).

Table 3.10 Age / Larger tires can increase fuel efficiency Crosstabulation

			False	True	Total
Age	18-24	Count	7	5	12
		% within Age	58.3%	41.7%	100.0%
	25-44	Count	19	11	30
		% within Age	63.3%	36.7%	100.0%
	45-64	Count	26	4	30
		% within Age	86.7%	13.3%	100.0%
	>65	Count	2	0	2
		% within Age	100.0%	0.0%	100.0%
Total		Count	54	20	74
		% within Age	73.0%	27.0%	100.0%

e) Age - Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack

There is a statistically significant difference in the percentages of the right answers to the question if "Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack" (answers: True, False) and the age of the responders. In this question, 100% of the age group 18-24 gave the right answer, while 80% of the responders belonging in the age group 45-64 gave the right answer. The percentages of success of the other two age groups were <75% (p-value=0.0466). (Table 4.10).

Table 3.11 Age / Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack Crosstabulation

			False	True	Total
Age	18-24	Count	12	0	12
		% within Age	100.0%	0.0%	100.0%
	25-44	Count	22	8	30
		% within Age	73.3%	26.7%	100.0%
	45-64	Count	24	6	30
		% within Age	80.0%	20.0%	100.0%
	>65	Count	1	1	2
		% within Age	50.0%	50.0%	100.0%
Total		Count	59	15	74
		% within Age	79.7%	20.3%	100.0%

f) Age - When driving on a downhill with a new technology car, fuel consumption is lower when

There is a statistically significant difference of the percentages of the right answers to the question “When driving on a downhill with a new technology car, fuel consumption is lower when..” (answers: The throttle is left and the appropriate gear in the gearbox has been chosen, the first gear in the gearbox is selected and the throttle is slightly pressed, we put the gear lever in the "dead" position) and the age of the responders. In this question, 100% of the age group >65 gave the right answer, while 73.3% of the responders belonging in the age group 45-64 gave the right answer. The percentages of success of the other two age groups were <70%. (Table 4.11)

Table 3.12 Age / When driving on a downhill with a new technology car, fuel consumption is lower when Crosstabulation

			The throttle is left and the appropriate gear in the gearbox has been chosen	The first gear in the gearbox is selected and the throttle is slightly pressed	We put the gear lever in the "dead" position	Total
Age	18-24	Count	7	5	0	12
		% within Age	58.3%	41.7%	0.0%	100.0%
	25-44	Count	20	7	3	30
		% within Age	66.7%	23.3%	10.0%	100.0%
	45-64	Count	22	4	4	30
		% within Age	73.3%	13.3%	13.3%	100.0%
	>65	Count	2	0	0	2
		% within Age	100.0%	0.0%	0.0%	100.0%
Total		Count	51	16	7	74
		% within Age	68.9%	21.6%	9.5%	100.0%

g) Age - Which is the proper action in order to reduce noise production while driving

There is a statistically significant difference of the percentages of the right answers to the question “Which is the proper action in order to reduce noise production while driving” (answers: Continuously fluctuate with the same gear in gearbox, Use the horn only in cases of congestion, Avoid abrupt braking, if not absolutely necessary) and the age of the responders. In this question, 80% of the age group 45-64 gave the right answer, while 66.7% of the responders belonging in the age group 25-44 gave the right answer. The percentages of success of the other two age groups (18-24 & >65) were 50% (p-value=0.05). (Table 4.12)

Table 3.13 Age / Which is the proper action in order to reduce noise production while driving Crosstabulation

			Continuously fluctuate with the same gear in the gearbox	Use the horn only in cases of congestion	Avoid abrupt braking, if not absolutely necessary	Total
Age	18-24	Count	4	2	6	12
		% within Age	33.3%	16.7%	50.0%	100.0%
	25-44	Count	7	3	20	30
		% within Age	23.3%	10.0%	66.7%	100.0%
	45-64	Count	5	1	24	30
		% within Age	16.7%	3.3%	80.0%	100.0%
	>65	Count	0	1	1	2
		% within Age	0.0%	50.0%	50.0%	100.0%
Total		Count	16	7	51	74
		% within Age	21.6%	9.5%	68.9%	100.0%

h) Resident - When driving on a downhill with a new technology car, fuel consumption is lower when

There is a significant difference of the percentages of the right answers to the question “When driving on a downhill with a new technology car, fuel consumption is lower when:..” (answers: The throttle is left and the appropriate gear in the gearbox has been chosen, the first gear in the gearbox is selected and the throttle is slightly pressed, we put the gear lever in the "dead" position) and permanent residency of the responders. In this question, 72.7% of the responders who live in the district of Rethymno but outside the city answered right. In comparison, 54.4% of the responders who have their permanent resident outside the district of Rethymno, gave the right answer. (Table 4.13)

Table 3.14 Resident / When driving on a downhill with a new technology car, fuel consumption is lower when Crosstabulation

			The throttle is left and the appropriate gear in the gearbox has been chosen	The first gear in the gearbox is selected and the throttle is slightly pressed	We put the gear lever in the "dead" position	Total
Resident	Inside the city	Count	37	12	3	52
		% within Resident	71.2%	23.1%	5.8%	100.0%
	Outside of the city	Count	8	1	2	11
		% within Resident	72.7%	9.1%	18.2%	100.0%
	Outside of the district of Rethymno	Count	6	3	2	11
		% within Resident	54.5%	27.3%	18.2%	100.0%
Total		Count	51	16	7	74
		% within Resident	68.9%	21.6%	9.5%	100.0%

i) Vehicle type - Fuel consumption is more efficient at low speeds

There is a significant difference in the percentages of the right answers to the question “Fuel consumption is more efficient at low speeds” (answers: True, False) and the type of the vehicle which use the responders. In this question, 100% of the responders who use public transportation answered right, while 50% of the responders who drive motor and both bicycle and motor vehicle gave the right answer. The responders who drive a car and both motor and car had a low percentage of success in this question (<50%). (Table 4.14)

Table 3.15 Vehicle type / Fuel consumption is more efficient at low speeds Crosstabulation

			False	True	Total
Vehicle type	Car	Count	29	22	51
		% within Vehicle type	56.9%	43.1%	100.0%
	Motor	Count	2	2	4
		% within Vehicle type	50.0%	50.0%	100.0%
	Car and motor	Count	8	5	13
		% within Vehicle type	61.5%	38.5%	100.0%
	Public transportation	Count	0	3	3
		% within Vehicle type	0.0%	100.0%	100.0%
	Motor and tractor	Count	0	1	1
		% within Vehicle type	0.0%	100.0%	100.0%
	Motor and bicycle	Count	1	1	2
		% within Vehicle type	50.0%	50.0%	100.0%
Total		Count	40	34	74
		% within Vehicle type	54.1%	45.9%	100.0%

j) Vehicle type - Which is the proper action in order to reduce air pollution from petrol vehicles

There is a statistically significant difference of the percentages of the right answers to the question “Which is the proper action in order to reduce air pollution from petrol vehicles” (answers: The transmission system should be checked frequently, Prolonged use of low gearboxes should be avoided) and the type of the vehicle which use the responders. In this question, none of the responders who use public transportation answered right, while 50% of the responders who drive motor and both bicycle and motor vehicle gave the right answer. 35.3% of the responders who drive car and 84.6% of the responders who drive both motor and car gave the right answer. 75% of the responders who drive motor vehicle answer right (p-value=0.00142). (Table 4.15)

Table 3.16 Vehicle type / Which is the proper action in order to reduce air pollution from petrol vehicles Crosstabulation

			The transmission system should be checked frequently	Prolonged use of low gearboxes should be avoided	Total
Vehicle type	Car	Count	33	18	51
		% within Vehicle type	64.7%	35.3%	100.0%
	Motor	Count	1	3	4
		% within Vehicle type	25.0%	75.0%	100.0%
	Car and motor	Count	2	11	13
		% within Vehicle type	15.4%	84.6%	100.0%
	Public transportation	Count	3	0	3
		% within Vehicle type	100.0%	0.0%	100.0%
	Motor and tractor	Count	0	1	1
		% within Vehicle type	0.0%	100.0%	100.0%
	Motor and bicycle	Count	1	1	2
		% within Vehicle type	50.0%	50.0%	100.0%
Total		Count	40	34	74
		% within Vehicle type	54.1%	45.9%	100.0%

k) Gender - Larger tires can increase fuel efficiency

There is a statistically non-significant relationship (independence) between the gender of the responder and the answer to the question if “Larger tires can increase fuel efficiency” (answers: True, False) (x^2=3.222, p-value=0.073, Phi-value= 0.209). (Table 4.16 4.17 & 4.18). The majority of both women (60%) and men (79.6%) think that larger tires cannot increase fuel efficiency.

Table 3.17 Gender / Larger tires can increase fuel efficiency Crosstabulation

			False	True	Total
Gender	Male	Count	39	10	49
		% within Gender	79.6%	20.4%	100.0%
	Female	Count	15	10	25
		% within Gender	60.0%	40.0%	100.0%
Total		Count	54	20	74
		% within Gender	73.0%	27.0%	100.0%

Table 3.18 Gender / Larger tires can increase fuel efficiency Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.222[a]	1	.073		
Continuity Correction[b]	2.305	1	.129		
Likelihood Ratio	3.123	1	.077		
N of Valid Cases	74				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.76.
b. Computed only for a 2x2 table

Table 3.19 Gender / Larger tires can increase fuel efficiency Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.209	.073
	Cramer's V	.209	.073
N of Valid Cases		74	

l) Gender - Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack

There is a statistically non-significant relationship (independence) between the gender of the responder and the answer to the question if “Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack" (answers: True, False) (x^2=0.325, p-value=0.569, Phi-value= 0.066). (Table 4.19 4.20 & 4.21). The majority of both women (76%) and men (81.6%) believe that car loads affect fuel consumption when the objects are inside the car and not on the external roof rack.

Table 3.20 Gender / Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack Crosstabulation

			False	True	
Gender	Male	Count	40	9	49
		% within Gender	81.6%	18.4%	100.0%
	Female	Count	19	6	25
		% within Gender	76.0%	24.0%	100.0%
Total		Count	59	15	74
		% within Gender	79.7%	20.3%	100.0%

Table 3.21 Gender / Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.325[a]	1	.569		
Continuity Correction[b]	.070	1	.791		
Likelihood Ratio	.319	1	.572		
N of Valid Cases	74				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.07.

b. Computed only for a 2x2 table

Table 3.22 Gender / Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.066	.569
	Cramer's V	.066	.569
N of Valid Cases		74	

m) Gender - Fuel consumption is more efficient at low speeds

There is a statistically non-significant relationship of independence between the gender of the responder and the answer to the question if "Fuel consumption is more efficient at low speeds" (answers: True, False) (x^2=0.064, p-value=0.800, Phi-value= 0.029). (Table 4.22 4.23 & 4.24). The majority of both women (48%) and men (44.9%) think that fuel consumption is more efficient at low speeds.

Table 3.23 Gender / Fuel consumption is more efficient at low speeds Crosstabulation

			False	True	
Gender	Male	Count	27	22	49
		% within Gender	55.1%	44.9%	100.0%
	Female	Count	13	12	25
		% within Gender	52.0%	48.0%	100.0%
Total		Count	40	34	74
		% within Gender	54.1%	45.9%	100.0%

Table 3.24 Gender / Fuel consumption is more efficient at low speeds Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.064[a]	1	.800		
Continuity Correction[b]	.000	1	.995		
Likelihood Ratio	.064	1	.800		
N of Valid Cases	74				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 11.49.

b. Computed only for a 2x2 table

Table 3.25 Gender - Fuel consumption is more efficient at low speeds Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.029	.800
	Cramer's V	.029	.800
N of Valid Cases		74	

n) Permanent resident - Fuel consumption is more efficient at low speeds

There is a statistically non-significant (independence) relationship between the permanent resident of the responder and the answer to the question if "Fuel consumption is more efficient at low speeds" (answers: True, False) (x2=0.064, p-value=0.800, Phi-value= 0.029). (Table 4.25 4.26 & 4.27). The majority of the responders who have their permanent resident inside the district of Rethymno (inside the city 50% & inside the district but outside of the city of Rethymno 54.5%) think that Fuel consumption is more efficient at low speeds.

Table 3.26 Permanent resident / Fuel consumption is more efficient at low speeds Crosstabulation

			False	True	
Resident	Inside the city	Count	26	26	52
		% within Resident	50.0%	50.0%	100.0%
	Outside of the city	Count	5	6	11
		% within Resident	45.5%	54.5%	100.0%
	Outside of the district of Rethymno	Count	9	2	11
		% within Resident	81.8%	18.2%	100.0%
Total		Count	40	34	74
		% within Resident	54.1%	45.9%	100.0%

Table 3.27 Permanent resident / Fuel consumption is more efficient at low speeds
Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.086[a]	2	.130
Likelihood Ratio	4.422	2	.110
Linear-by-Linear Association	2.628	1	.105
N of Valid Cases	74		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.05.

Table 3.28 Permanent resident / Fuel consumption is more efficient at low speeds
Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.235	.130
	Cramer's V	.235	.130
N of Valid Cases		74	

Chapter 5. Results of young drivers real-life behavior test

The results of the OBD data are listed below in two sections. The first section contains information and graphs related to the nine eco-driving events that captured with the OBD device and presents the streets inside the city of Rethymno, where the implementation of eco-driving is difficult. The second section contains information about the high concentration of CO_2 emissions due to the non-implementation of eco-driving principles or due to the difficulty of the implementation on the roads. The plotted areas and spots have instantaneous CO_2 values over 180 g/s.

5.1.1. Eco-driving events analysis

After the analysis of the eco-driving events using Python software, the streets and the spots of every event are presented below using Tableau Public.

a. Accelerating Sharply

This event was recognized using the acceleration from the OBD device. When a car for a period of time has an acceleration more than 4km/h/s is identified as one Accelerating Sharply event and it was recognized 702 (16,300 times acceleration value, was smaller than 4km/h/s and higher than 1 km/h/s) times during the analysis of the OBD data.

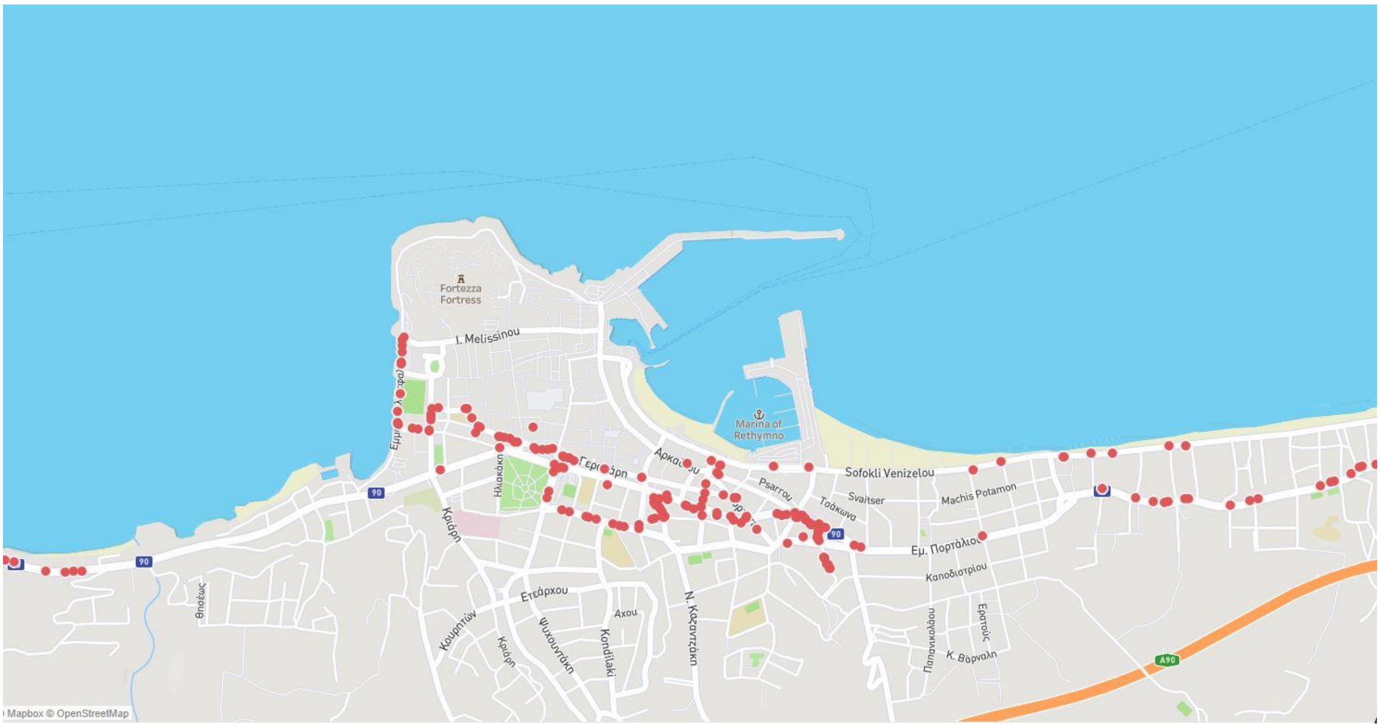


Figure 3.5 Heat map of accelerating sharply event

As can be seen from the map, accelerating sharply events, are spotted mainly on the mainline of the city of Rethymno, close to the city garden. Traffic jams in this area is a common phenomenon.

b. Decelerating Sharply

This event was recognized using the acceleration from the OBD device. When a car for a period of time has an acceleration lower than 5 km/h/s is identified as one Decelerating Sharply event and spotted 229 times (3,986 times acceleration value, was smaller than 0km/h/s and higher than -5 km/h/s) during the analysis of the OBD data.

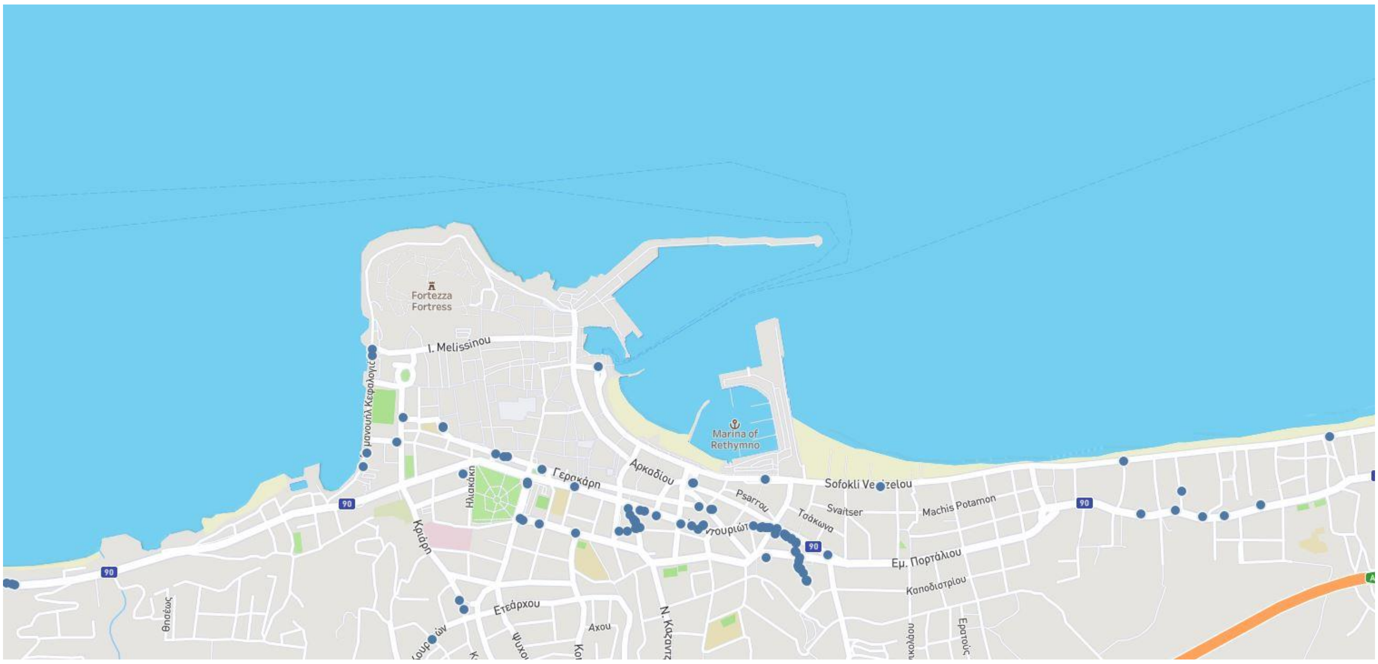


Figure 3.6 Heat map of decelerating sharply event

As it was expected, the area where events of accelerating sharply are spotted, decelerating sharply events are located too. The main roads of the city, close to the city garden, are those where these events are usually spotted due to the frequent traffic jams.

c. Long-time Accelerating

If the acceleration lasts more than 5s is identified as one Long-time Accelerating event and spotted 2290 times during the analysis of the OBD data.

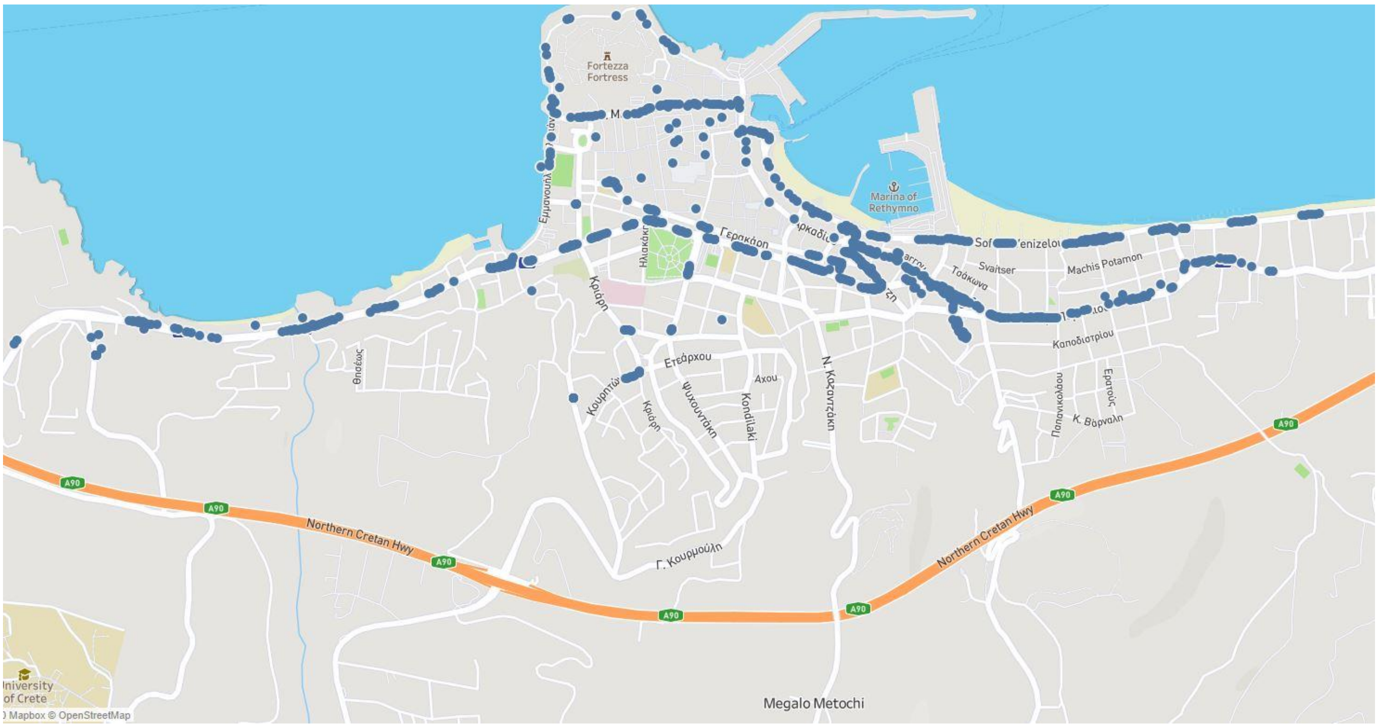


Figure 3.7 Heat map of the long-time accelerating event

Long-time accelerating events are spotted usually, where traffic lights and traffic jams are spotted too. In this way, the west side of the city and the main west roads which lead to the center of the city, are characterized by long-time accelerating events.

d. Long-time Idling

When the vehicle idles for more than 60s is identified as one Long-time Idling event and spotted 196 times during the analysis of the OBD data.

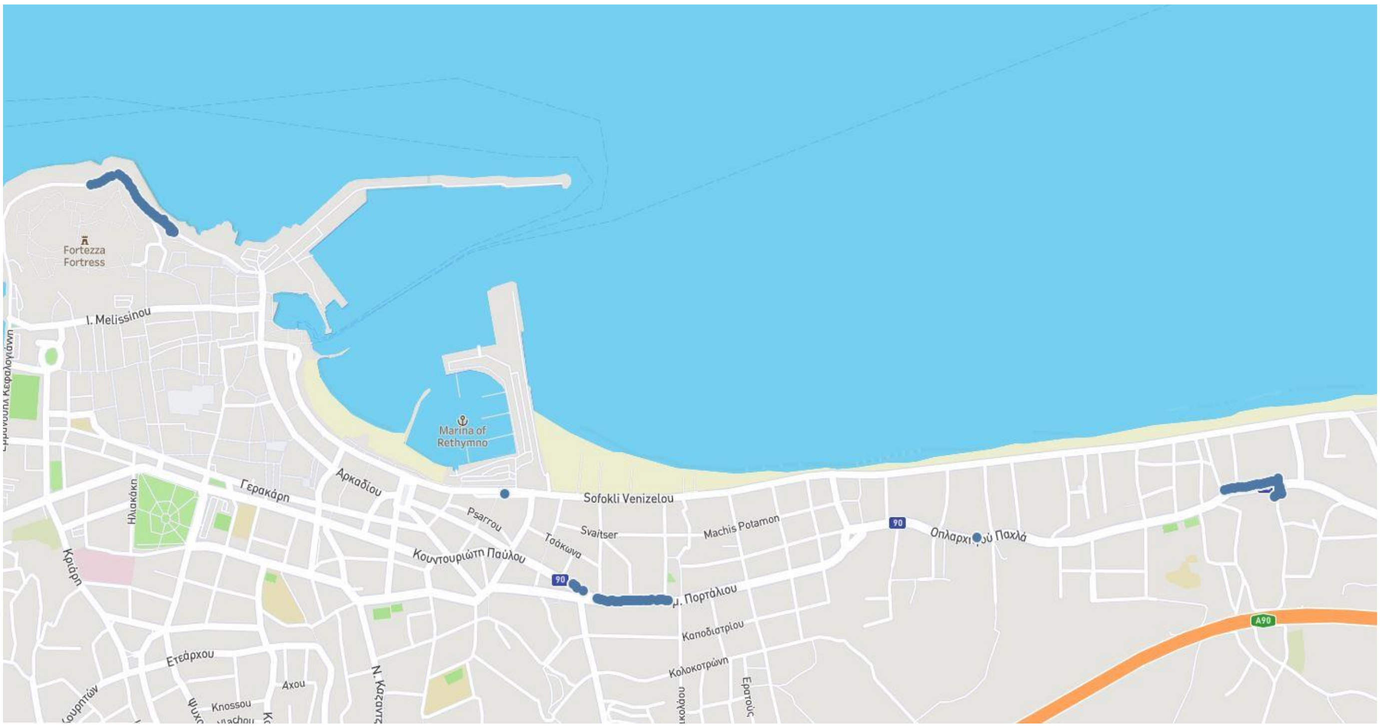


Figure 3.8 Heat map of the long-time idling event

As can be seen from the map, this event is spotted mainly on regional roads and not at any mainline of the city. This type of event is usually located during long time stoppages of the vehicle without turning off the engine.

e. Running with Low Speed

When the average speed of the vehicle is lower than 23 km/s during 60 consecutive s, the event is identified as one Running with Low-Speed event and it was recognized 2625 times during the analysis of the OBD data.

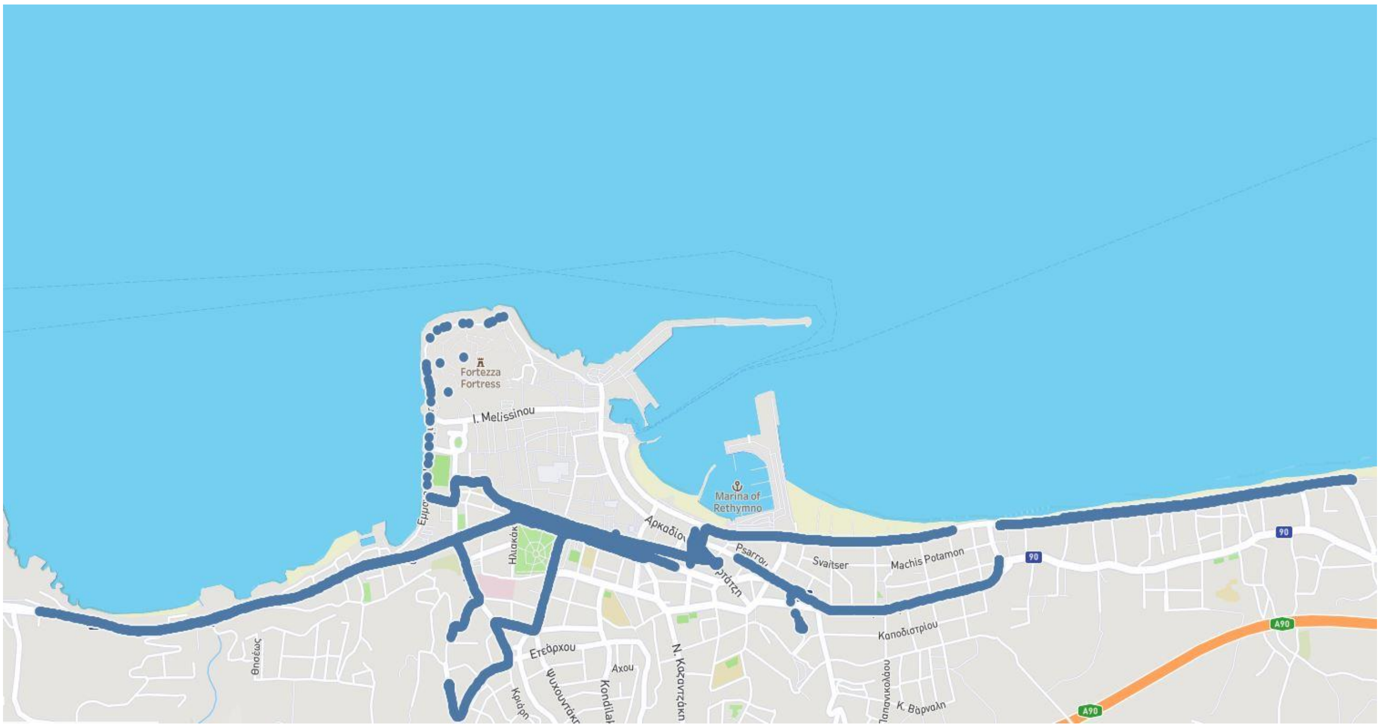


Figure 3.9 Heat map of running with low-speed event (23km/h)

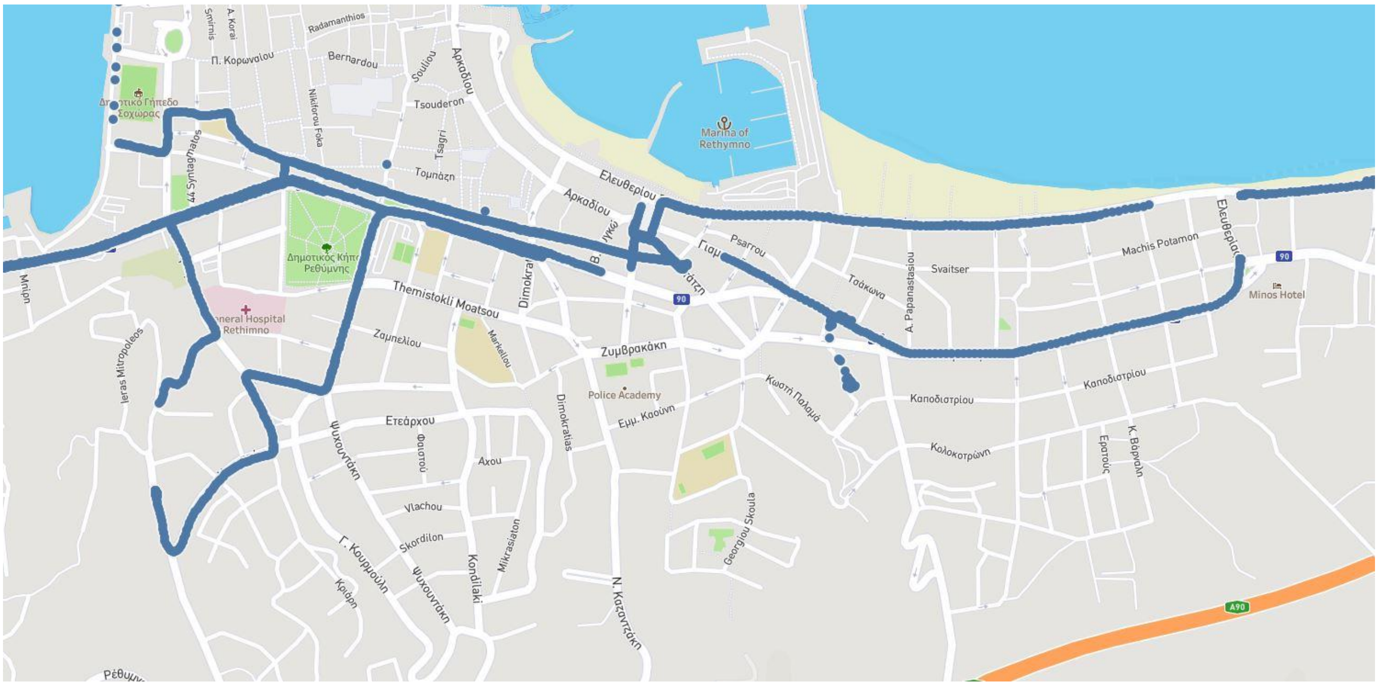


Figure 3.10 Heat map of running with low-speed event (23km/h) (rescaled)

The maps of “Running with low-speed” event, contain all the main roads of the city in order to reach the city center. Except for the road which leads to Fortezza Castle, the rest of them are illustrated on the map, with consecutive lines, a fact that reveals the high number of located events. The main roads, with numerous events of this type, are those from where vehicles enter the city, from the east and west side and main lines such as roads close to the city garden and near to city hospital.

f. Cruising with Higher Speed

During 5s of driving, the average speed is no less than 60km/h, or the instantaneous acceleration is no more than 1 km/h/s or speed standard deviation in no more than 1.5 km/h or speed variation is no more than 1 km/h. The event is identified as one Cruising with Higher Speed event and spotted 450 times during the analysis of the OBD data.

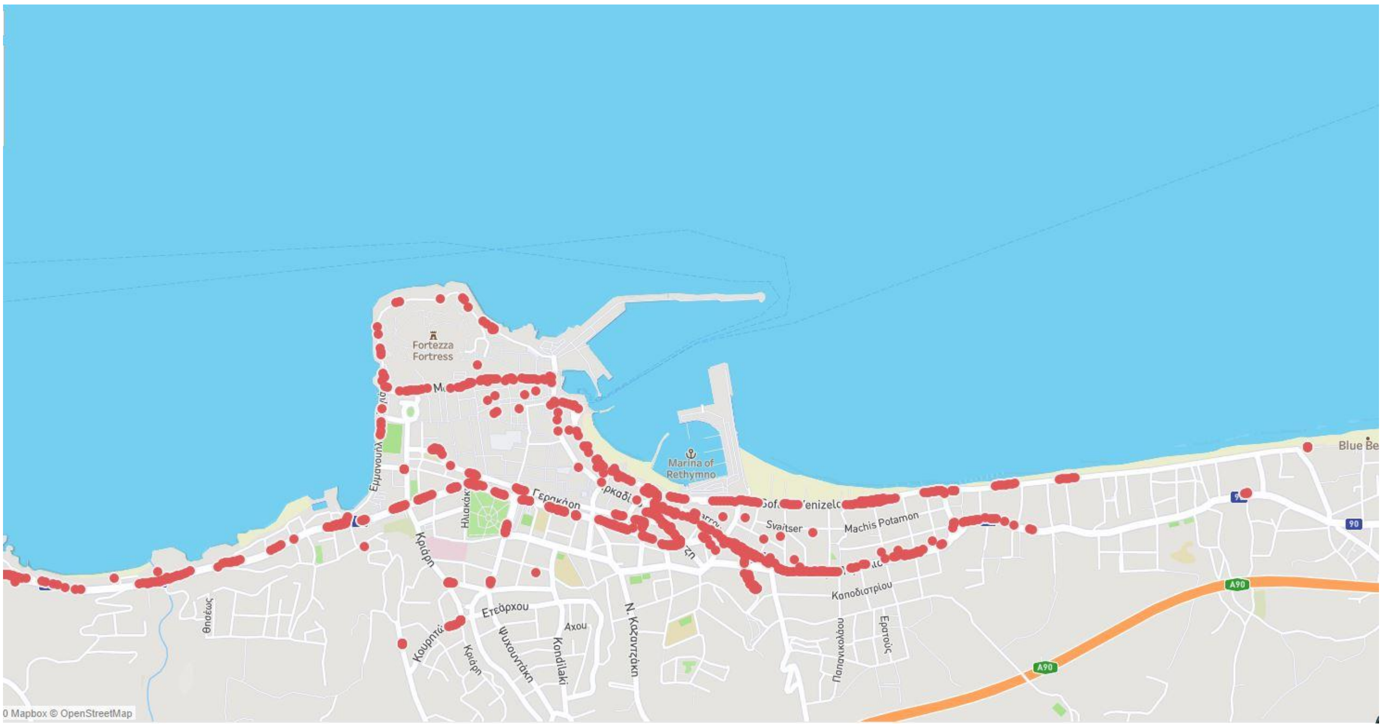


Figure 3.11 Heat map of cruising with higher speed event

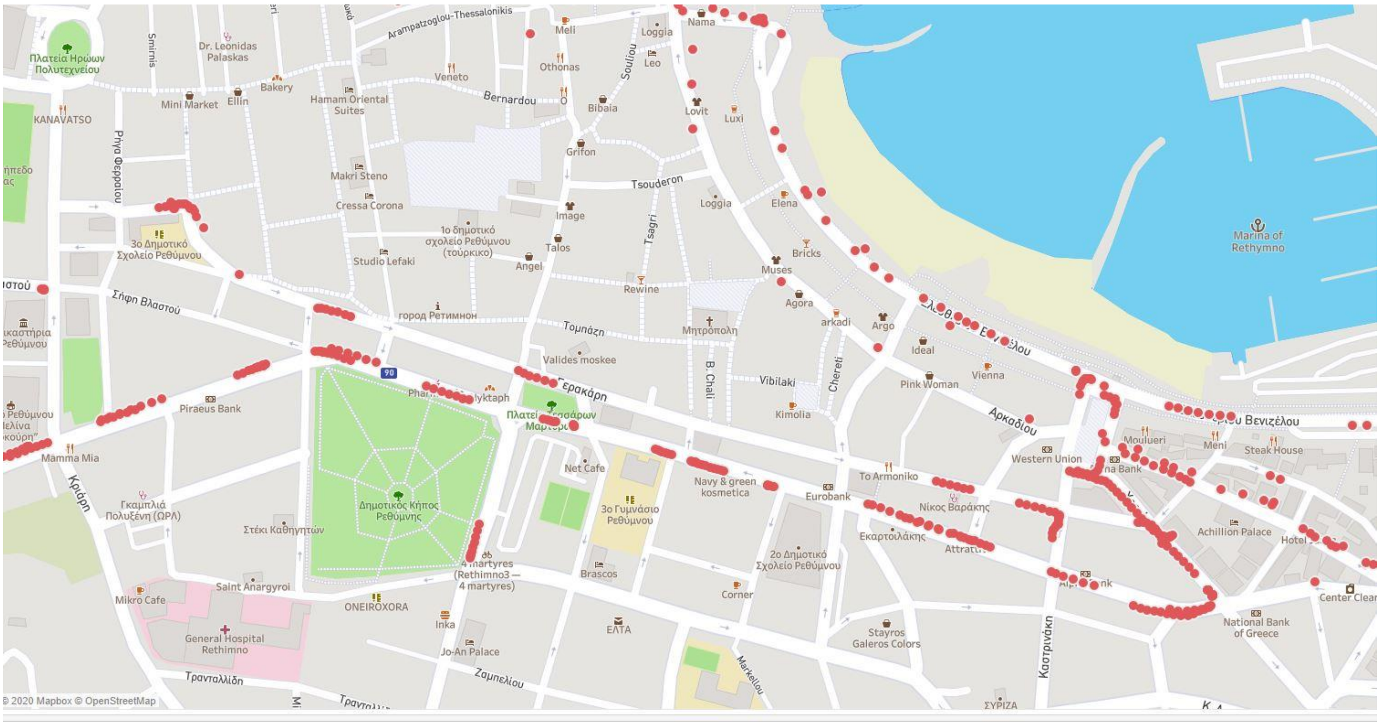


Figure 3.12 Heat map of cruising with higher speed event (rescaled)

This type of event is largely spotted on main roads and routes through the city of Rethymno.

g. Starting Moderately

When the vehicle accelerates from idling and its speed variation is higher than 10 km/h/s and lower than 20 km/h/s or maximum acceleration is no more than 4 km/h/s, during 5s the event identified as one Starting Moderately event and spotted 595 times during the analyzation of the OBD data.

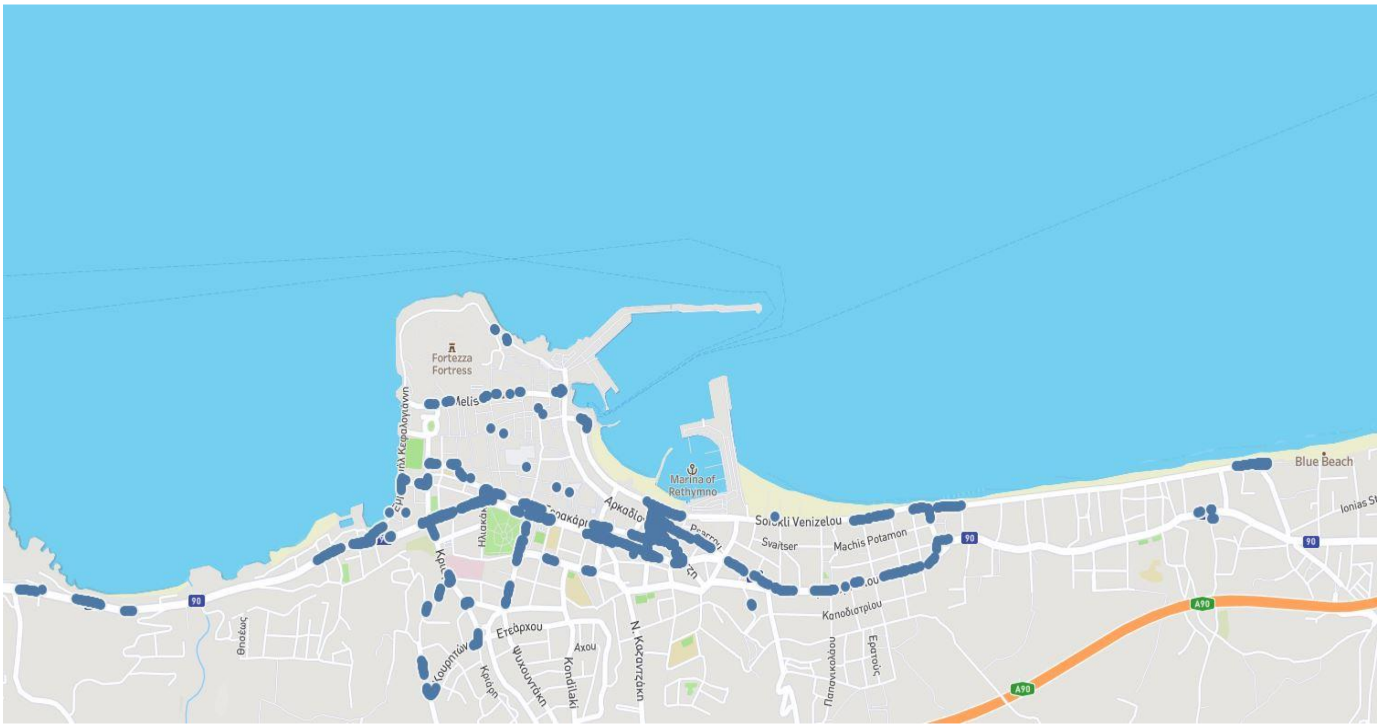


Figure 3.13 Heat map of starting moderately event

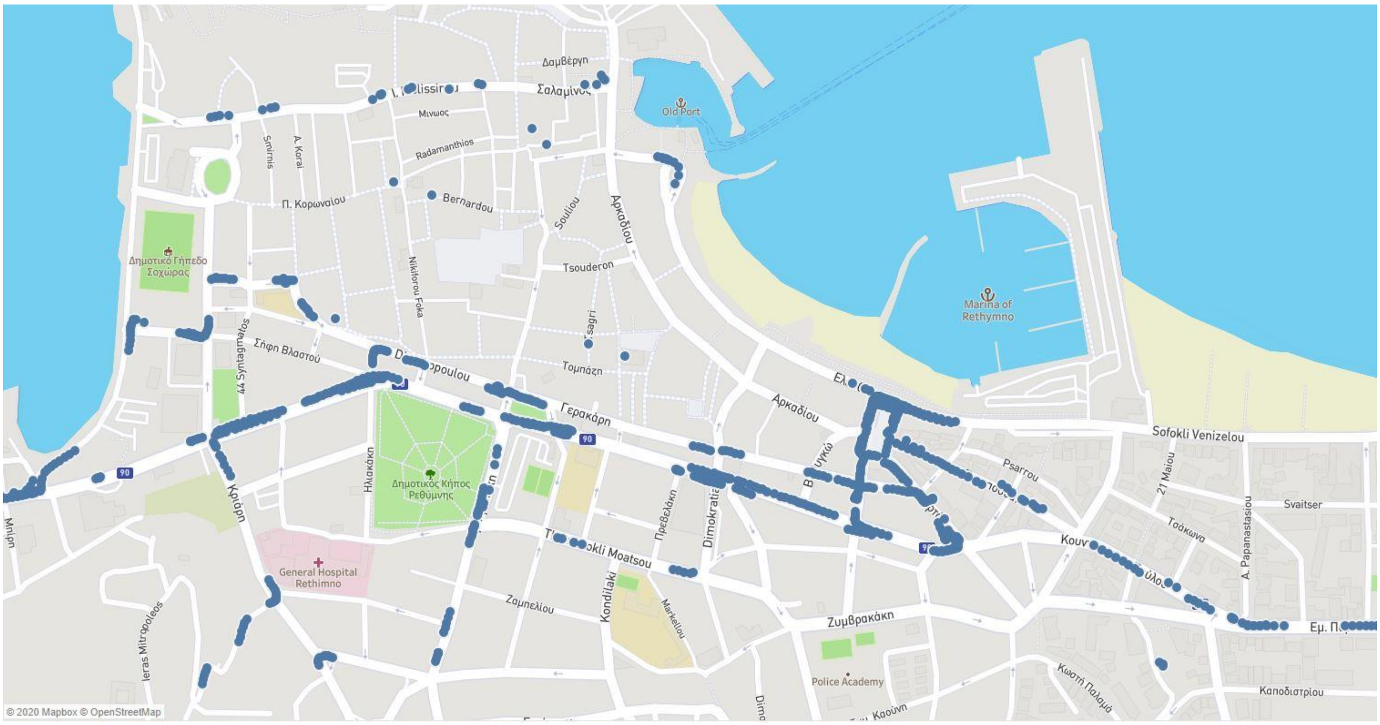


Figure 3.14 Heat map of starting moderately event (rescaled)

h. Frequently Stop and Start & Braking Moderately

When a vehicle idles within 3 s after starting from an idling, this period is identified as one Frequently Stop and Start event and spotted 66 times during the analysis of the OBD data. When the vehicle decelerating, during 5 s and deceleration is greater than -25 km/h/s and lower than -15 km/h/s or the minimum acceleration is no less than -5 km/h/s, this event identified as one Braking Moderately event and spotted 50 times during the analyzation of the OBD data.

Figure 3.15 Heat map of frequently stop and start & braking moderately event

A small number of this type of events were spotted on the main lines of the road, close to the city center and the city hospital.

5.1.2. CO_2 emissions

Once the driving events inside the city of Rethymno were spotted, the streets with a high concentration of CO_2 emissions were spotted too. The high concentrations are due to the non-implementation of eco-driving principles and were detected using the previous nine events. The plotted results are presented below. (4.12)

Figure 3.16 Heat map of CO_2 emissions in total

Figure 3.17 Heat map of CO_2 emissions in total (rescaled)

Figure 3.18 Heat map of CO_2 emissions (west side of Rethymno)

Figure 3.19 Heat map of CO_2 emissions in total (north-east side of Rethymno)

The roads with high CO_2 emissions are the main lines of the city where usually events such as traffic jams are observed too. Thus, the road close to the city garden and hospital, close to the port and KTEL (coastal roads) and some suburban roads are where this event is spotted. On the contrary, downtown streets due to the trafficking ring, have not high CO_2 emissions.

Chapter 6. Conclusions

Eco-driving is a style of driving that incorporates many advantages as the reduction of fuel consumption, reduction of CO_2 emissions, safety during transportation, the reduction of noise production and many others. The major disadvantage of this style of driving is the low information of the public about the advantages of eco-driving and thus, the low understanding of its nature, the ingrained driving habits complicating the implementation of eco-driving and the low levels of awareness of local citizens.

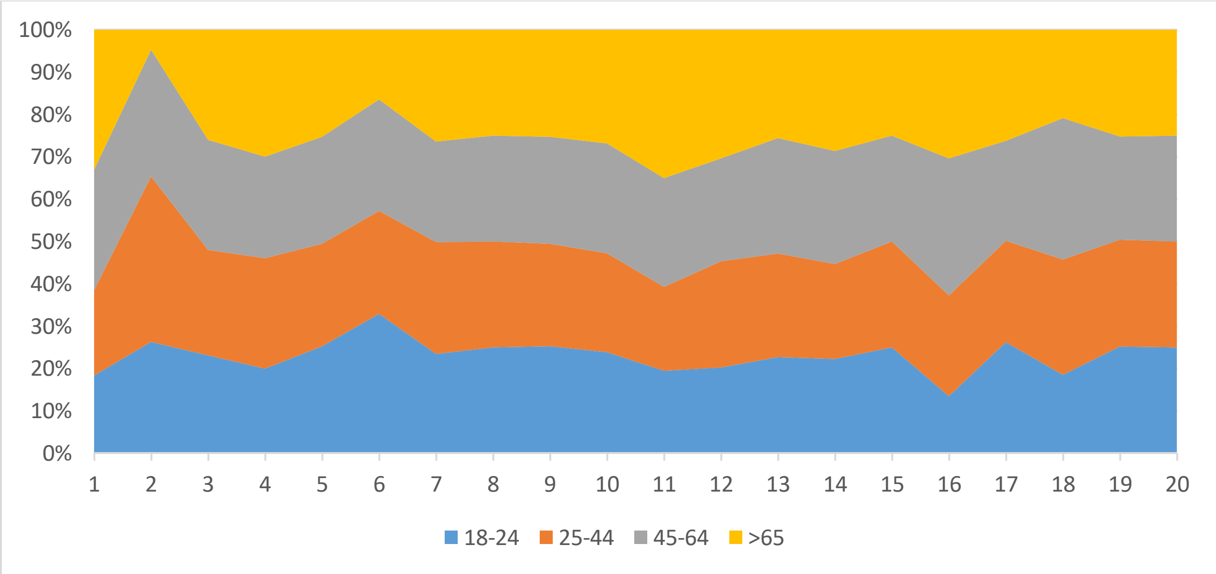
This study dealt with the problems mentioned above and aimed to raise public awareness about the implementation of eco-driving. The readiness of local citizens of Rethymno in Crete to implement this style of driving must be checked. The streets where the implementation of eco-driving can be considered as difficult must be spotted and the spots where due to the non-eco-driving style, CO_2 emissions from cars are high enough must be identified too. The adopted methodology, which applied in two stages, brought out interesting research results.

As it can be observed from the Graph 5.2 and 5.3, the age groups with the highest eco-driving knowledge /percentages of right answers were 45-64 and 24-44. On the other hand, the lower eco-driving knowledge /percentage of right answers belongs to the age group of 18-24. As for the gender, males had more right answers in comparison with females. By observing the graphs, we can spot the questions with the lowest percentages of right answers. More specifically, the questions with percentages of success lower than 70%, have to do with the "Economical driving," "Air pollution," and "Noise production" categories of the questionnaire:

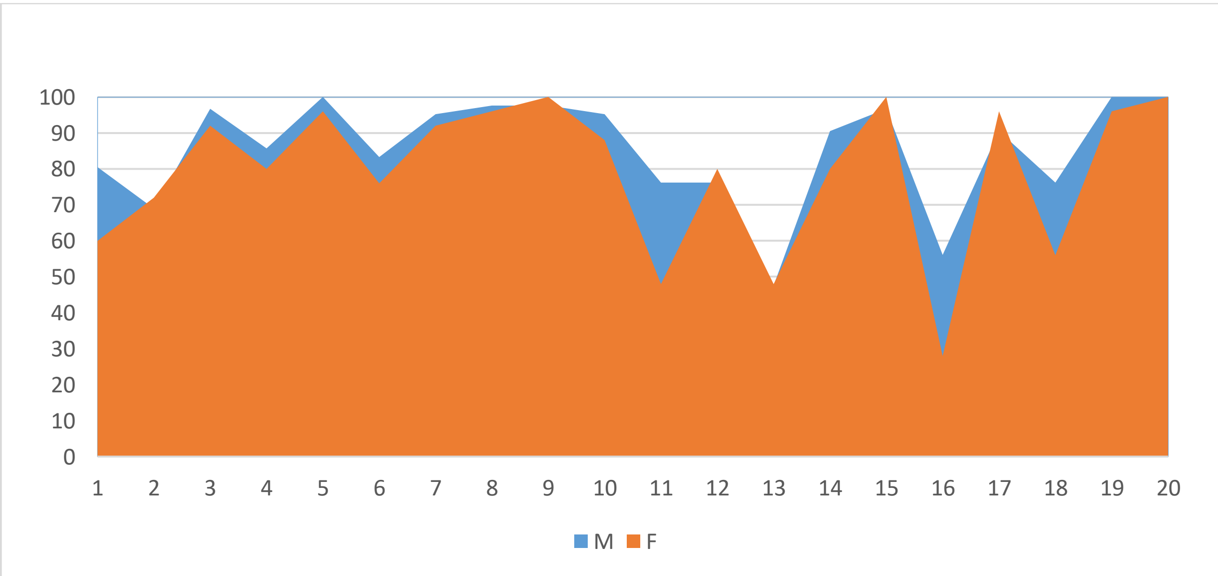
- No 11. For downhill driving with a new technology car, fuel consumption is lower when: (68.9 percentage of success)
- No 13. Fuel consumption is more efficient at low speeds: (54.1 percentage of success)
- No 16. Proper action "To reduce air pollution from gasoline-powered vehicles": (45.9 percentage of success)
- No 18. Proper action "To avoid noise production while driving": (68.9 percentage of success)

The percentages mentioned above of success have significant importance. The participants took part in the survey voluntarily and probably had an eco-driving sensibility.

Graph 6.21 Percentages of right answers per question and age groups



Graph 6.22 Percentages of right answers per question and gender.



By analyzing the statistical relations of the results of the questionnaire, some interesting finding can be observed:

- **Gender - Decrease of air pollution by petrol vehicles** While 56.1% of men believe that to avoid air pollution from petrol engines, it must be avoided the prolonged use of low gearboxes, 72% of women believe that the right answer is the check of the transmission system frequently.
- **Gender - When driving on a downhill with a new technology car, fuel consumption is lower when** 79.6% of males gave the right answer, while 48% of females answered right. There is a statistical significant difference in the percentages of the right answers between the question and the gender of the responders. Probably men are more knowledgeable about eco-driving with technology cars.
- **Gender - Which is the proper action in order to reduce noise production while driving** 75.5% of males gave the right answer, while 56% of females answered right. It seems that men are more knowledgeable about proper actions on the operation/eco-driving of the car.
- **Age - Larger tires can increase fuel efficiency** 100% of the group of age >65 gave the right answer, while 86.7% of the responders belonging in the group of ages 45-64 gave the right answer. The percentages of success of the other two groups were <65% (18-24, 58.3% &25-44, 63.3%). It seems, the older you get, the wiser/knowledgeable you become about eco-driving aspects of the car.
- **Age - Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack** 100% of the group of age >65 gave the right answer, while 73.3% of the responders belonging in the group of ages 45-64 gave the right answer. The percentages of success of the other two groups were <70%.
- **Age - When driving on a downhill with a new technology car, fuel consumption is lower when** 80% of the group of age 45-64 gave the right answer, while 66.7% of the responders belonging in the group of ages 25-44 gave the right answer. The percentages of success of the other two groups (18-24 & >65) were 50%. The older seems to be more knowledgeable about eco-driving aspects/operation of the car.
- **Residence - Which is the proper action in order to reduce noise production while driving** 72.7% of the responders who live in the district of Rethymno but outside of the city answered right, while 71.2% of the

responders who live inside the city of Rethymno gave the right answer. 54.4 of the responders who have their permanent resident outside the district of Rethymno, gave the right answer.

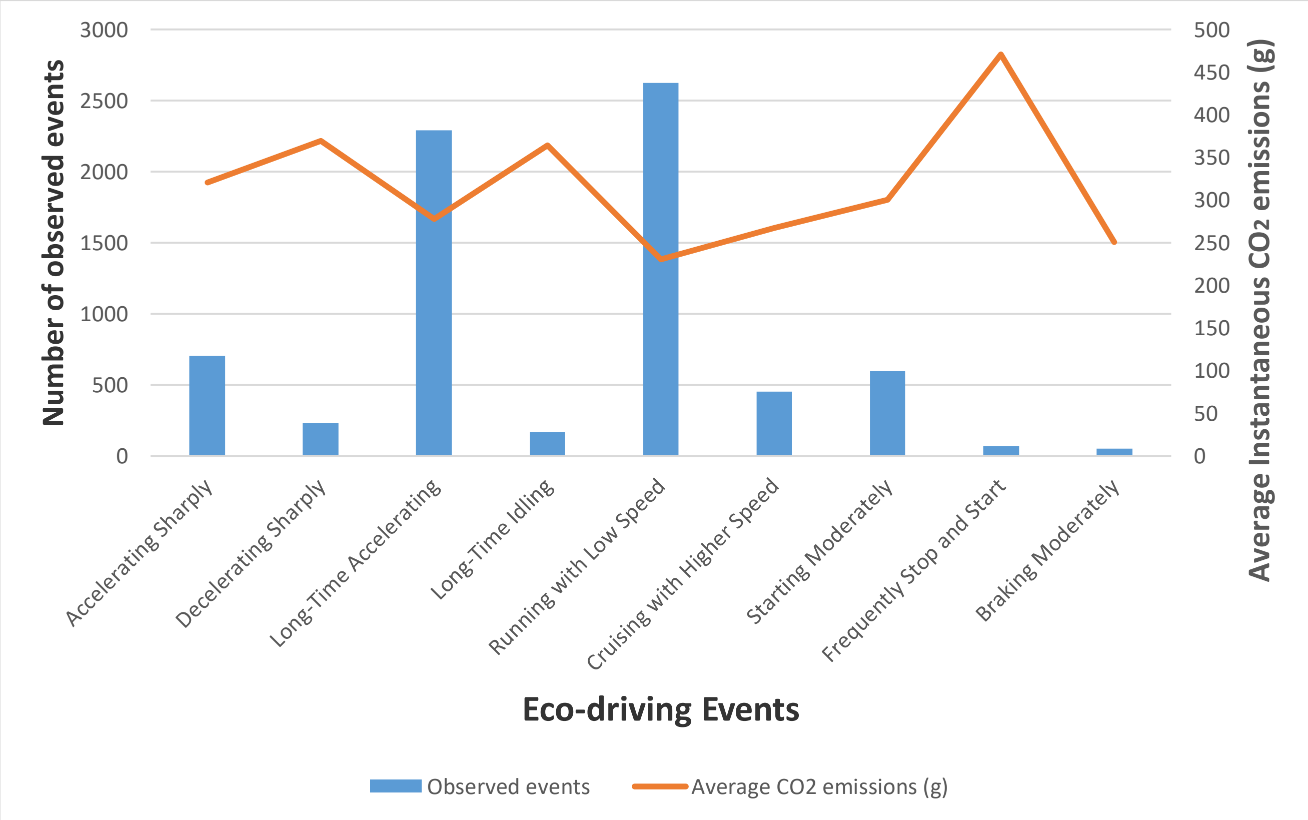
- **Vehicle - When driving on a downhill with a new technology car, fuel consumption is lower when** 100% of the responders who use public transportation answered right. At the same time, 50% of the responders who drive motor and both bicycle and motor vehicle gave the right answer. The responders who drive a car and both motor and car had a low percentage of success in this question (<50%).
- **Vehicle type - Fuel consumption is more efficient at low speeds** 100% of the responders who use public transportation answered right, while 50% of the responders who drive motor and both bicycle and motor vehicle gave the right answer. The responders who drive car and both motor and car had low percent of success in this question (<50%).
- **Vehicle type - Which is the proper action in order to reduce air pollution from petrol vehicles** 35.3% of the responders who drive car and 84.6% of the responders who drive both motor and car gave the right answer. 75% of the responders who drive motor vehicle answered right
- **Gender - Larger tires can increase fuel efficiency** The majority of both women (60%) and men (79.6%) think that larger tires cannot increase fuel efficiency. We can assume that both males and females are familiar with this topic.

- **Gender - Car loads do not affect fuel consumption when the objects are inside the car and not on the external roof rack** The majority of both women (76%) and men (81.6%) believe that car loads affect fuel consumption when the objects are inside the car and not on the external roof rack. There is a statistical independence relationship between the two questions.

- **Gender - Fuel consumption is more efficient at low speeds** The minority of women (48%) and men (44.9%) think that fuel consumption is more efficient at low speeds. Both genders have low percentages of success in this question. The two questions have a statistical relation of independence between them.

- **Permanent resident - Fuel consumption is more efficient at low speeds**
The majority of the responders who have their permanent resident inside the district of Rethymno (inside the city 50% & inside the district but outside of the city of Rethymno 54.5%) think that Fuel consumption is more efficient at low speeds.

Graph 6.23 Frequency of observed eco-driving events in comparison with their average instantaneous CO_2 emissions (g)



In the second part of the research, five volunteer drivers belonging to age group 18-24, mounted OBD devices on their cars. Analyzing the data collected during 3 months, nine events related to eco-driving principles, identified using Python programming language. Those nine events constituted a way to spot the streets in the city of Rethymno that implement the eco-driving makes it even harder. As it can be noticed from the graph 5.3, the events of Long-time acceleration and Running with low speed were the most observed. Accelerating and decelerating sharply observed 702 and 229 times correspondingly, while Frequently stop and start (66 times) and Braking moderately (50) had the fewest observations.

On the other hand, the event of Frequently stop and start had the most significant contribution to CO_2 emission production every time that it was observed (on average 470.42 g). Braking moderately was the event with the lowest number of observations and the least contribution of CO_2 emission production. The two events with the largest number of observations, had the lowest contribution to CO_2 emission production, in comparison with the other seven events except Barking moderately.

Analyzing the heat maps from Tableau Public software, the streets of every separate event that observed can be recognized.

1. **Accelerating Sharply:** Leof. Emmanouil Kefalogianni, Street of Moatsou, streets around city garden, and the street of Igoumenou Gavriil.

2. **Decelerating Sharply:** Leof. Stamathioudaki, Leof. Emmanouil Kefalogianni, street of Sifi Vlastou, street of Moatsou and Leof. Dimokratias

3. **Long-Time Accelerating:** Leof. Stamathioudaki, street of Ioannou Melisinnou, street of Kountouriotou, Giampoudaki, Mark. Portaliou and Leof. El. Benizelou

4. **Long-Time Idling:** Street of Mark. And Emmanouil Portaliou, Leof. Pachla, Emannouil Kefalogianni (near the old Venetian Port)

5. **Running with Low Speed:** Streets of Ari Velouchioti, Igoumenoy Gavriil, Moatsou, Mark. And Emannouil Portaliou, streets around General Hospital and Leof. Stamathioudaki

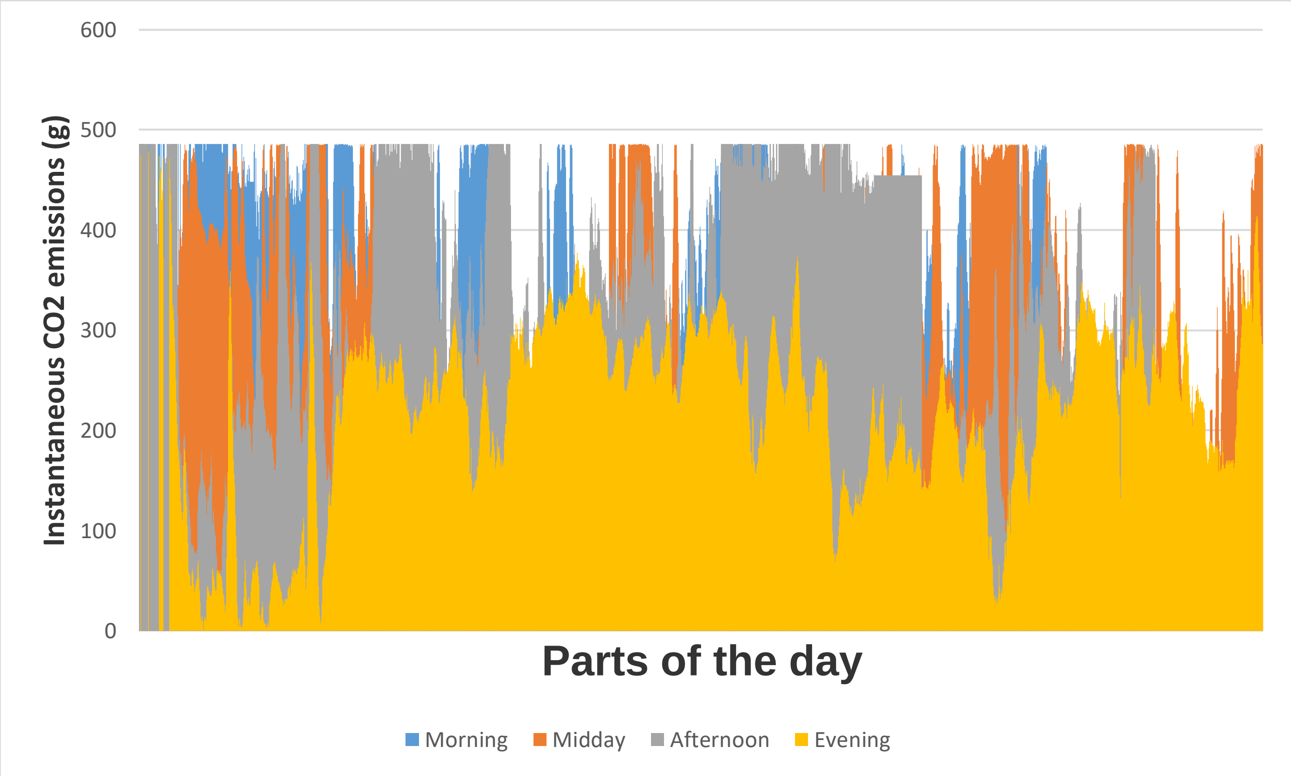
6. **Cruising with Higher Speed:** Streets of Gerakari-Arkadiou, Mark. And Emannouil Portaliou, Igoumenou Gavriil and Kountouriotou and Ioannou Melisinnou.

7. **Starting Moderately:** Streets around general Hospital, Gerakari-Arkadiou, Mark. And Emannouil Portaliou, Igoumenou Gavriil and Kountouriotou

8&9. **Frequently Stop and Start & Braking Moderately:** Leo. Stamathioudaki, street of Gerakari, Igoumenou Gavriil and Kountouriotou

Leoforos Stamathioudaki and the streets of Kountouriotou, Mark, and Emannouil Portaliou and near the city garden spotted as the streets where the largest number of events identified.

Graph 6.24 CO_2 emissions during the day



By observing the graph 5.4, the part of the day where the vehicles in this research, produced CO_2 the most, was in the morning, while on the midday, produced CO_2 the least. Finally, analyzing the heat maps from the Tableau Public software, the spots with the most intense production of CO_2 emissions are:

- Street of Sofokli Venizelou
- The area around the general hospital of the city
- The area close to KTEL and near the sea (Leof. Stamathioudaki)

- Marina
- Downtown streets and area close to and around the city garden

Chapter 7. Discussion and recommendations for further research

The city of Rethymno in Crete has made a few crucial steps towards sustainable mobility in the past few years and it has been recognized for implementing policies promoting green energy and sustainable movement. Citizens themselves have an essential role in decision making, as local authorities take public opinion into account, on the application of practices and laws to facilitate them. Rethymno is also a city that has attracted considerable interest in recent years, with the implementation of campaigns promoting safe and green driving and the European Union and European programs have supported it as an example of a sustainable city.[45,46]

The implementation of this diploma thesis methodology, was a step forward, in order, age groups and gender that are facing difficulties with the implementation of eco-driving, to be identified. Also, identified groups of practices and habits that are not implemented in the right way to avoid noise production increased fuel consumption and high CO_2 emissions productions. Overall, results brought out four different statistical cor (relations), comparing specified-answer questions such as demographic information of the responders with twenty questions related to eco-driving principles: i. statistically significant dependence relationships ii. statistically non-significant (independence) relationships iii. statistically significant difference in the percentages of the right answers and iv. significant difference in the percentages of the right answers. The independence test spotted similar answers between the responders' vehicle, their permanent resident and the questions of the questionnaire. Also, similar opinions about eco-driving principles spotted too, investigating the answers of the genders, the age groups and the permanent residency of the responders. Finally, the answers of the responders in relation to the vehicles that they are used to drive are noteworthy.

As for the improvement of the survey, it is suggested, the number of the responders to be increased in order, dependence and independence statistical relations to be increased too. Furthermore, analyzing the results of the survey, it is suggested, the addition of more difficult and open-ended questions.

Furthermore, this thesis identified streets and spots facing problems with traffic jams that need decongestion. Streets with high production of harmful emissions due to the motor vehicles identified, too, using a new method to test eco-driving performance. After the recognition of nine anti-eco-driving events, the streets of Rethymno, where each event has a multiple number of appearances, located too and presented on different maps.

Finally, it is suggested the methodology mentioned above be enriched by increasing the number of volunteers that can mount OBD devices, its implementation during summer months to evaluate the impact of the tourist period.

Therefore, it is suggested, the usage of this study to decongest all these spots and streets for the drivers and the citizens to savor the benefits of eco-driving. Interventions could achieve this in street infrastructures, often checking the traffic lights for possible faults, creations of parking lots, new bicycle infrastructures must be increased, such as the number of bicycles on the streets and the settlement of traffic jams from local police authorities.

Local citizens and drivers of ages (18-24) must be well informed about the benefits of eco-driving and the implementation methods. Citizens must be informed about the benefits of alternative technologies vehicles too.

The idea of electrification must be introduced and public awareness about clean transportation must be raised. Rethymno, where the methodology of this thesis implemented, is a city where every year is awarded due to its innovation and low-carbon policies and infrastructures. Rethymno, both Karditsa, has already installed charging infrastructures for electric vehicles, while electric buses run into the cities.

Finally, a machine learning model could be structured to evaluate the impact of high traffic conditions for all the months of the year. The functionality of the OBD devices allows users to send their information from their vehicles, live to a database. This could be used with the combination of a machine learning model not only to evaluate the impact of high traffic conditions but to predict them.

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Annex A

In this section, Eco-driving survey, can been seen.

Quiz Οικολογικής Οδήγησης

Με την οικολογική οδήγηση, εξοικονομούμε ενέργεια, χρήματα, προστατεύουμε το περιβάλλον και μειώνουμε την ηχορύπανση.

Συμπλήρωσε το παρακάτω κουίζ, και δες σε ποια «ενεργειακή κατηγορία» οδηγού ανήκεις! Για κάθε σωστή απάντηση, πρόσθεσε έναν πόντο. Έλεγξε τις σωστές απαντήσεις, πρόσθεσε τους πόντους σου, δες πόσο καλά γνωρίζεις τις αρχές της οικολογικής οδήγησης και ακολούθησε τις στις επόμενες μετακινήσεις σου!

Ελαστικά

1. Τα ελαστικά με μεγαλύτερο πέλμα αυξάνουν την απόδοση καυσίμου. ☐ Σωστό ☐ Λάθος

2. Η πίεση των ελαστικών θα πρέπει να ελέγχεται τουλάχιστον:

α. μια φορά τον μήνα ☐
β. μια φορά στους τρείς μήνες ☐
γ. μια φορά τον χρόνο ☐

Στάσεις

3. Επαναλαμβανόμενες μικρής διάρκειας στάσεις του οχήματος, συμβάλλουν στην αύξηση της κατανάλωσης του καυσίμου. ☐ Σωστό ☐ Λάθος

4. Κατά τη διάρκεια μιας στάσης διάρκειας μεγαλύτερης από 1 λεπτό, είναι καλύτερο το όχημα:

α. να παραμείνει σβηστό ☐
β. να παραμένει με ταχύτητα με πατημένο συμπλέκτη ☐
γ. να είναι ακινητοποιημένο στο ρελαντί ☐

Παράθυρα

5. Η κατανάλωση καυσίμου αυξάνεται:

α. με ανοικτά παράθυρα ☐
β. με κλειστά παράθυρα ☐
γ. με κλειστή ηλιοροφή ☐

Μεταφορά φορτίου

6. Η μεταφορά φορτίων με το αυτοκίνητό δεν επηρεάζει την κατανάλωση καυσίμου, όταν τα αντικείμενα βρίσκονται μέσα στο αυτοκίνητο και όχι σε εξωτερική σχάρα οροφής.
☐ Σωστό ☐ Λάθος

7. Η οδήγηση με σχάρα στην οροφή ακόμα και χωρίς φορτίο:

α. αυξάνει την κατανάλωση ☐
β. μειώνει την κατανάλωση ☐
γ. δεν επηρεάζει την κατανάλωση ☐

Οικονομική οδήγηση

8. Οικονομική οδήγηση μπορεί να επιτευχθεί:

α. με μειωμένη πίεση των ελαστικών ☐
β. με οδήγηση σε αυξημένες στροφές του κινητήρα ☐
γ. με τη σωστή πίεση των ελαστικών ☐

9. Η χρήση του κλιματιστικού:

α. αυξάνει την κατανάλωση ☐
β. μειώνει την κατανάλωση ☐
γ. δεν επηρεάζει την κατανάλωση ☐

10. Οικονομικότερη οδήγηση σε δρόμο χωρίς κλίση επιτυγχάνεται:

α. αυξομειώνοντας συνεχώς ταχύτητα με την ίδια σχέση στο κιβώτιο ταχυτήτων ☐
β. αλλάζοντας συνεχώς ταχύτητες στο κιβώτιο ταχυτήτων ☐
γ. χρησιμοποιώντας την κατά περίπτωση μεγαλύτερη σχέση μετάδοσης με σταθερή ταχύτητα ☐

11. Για οδήγηση σε κατήφορο με αυτοκίνητο νέας τεχνολογίας, η κατανάλωση καυσίμου είναι μικρότερη:

α. αφήνοντας το γκάζι και έχοντας επιλέξει την κατάλληλη σχέση στο κιβώτιο ταχυτήτων ☐
β. βάζοντας τον μοχλό ταχυτήτων στη θέση «νεκρά» ☐
γ. επιλέγοντας την πρώτη σχέση στο κιβώτιο ταχυτήτων, πατώντας ελαφρά το γκάζι ☐

12. Ποιος ο αριθμός των στροφών (RPM) που θα πρέπει να αλλάζει η ταχύτητα μετάδοσης, προκειμένου να ελαχιστοποιηθεί η κατανάλωση καυσίμου;

α. 2.000-2.500 ☐
β. 1.000-1.500 ☐
γ. 3.000-4.000 ☐

13. Η κατανάλωση καυσίμου είναι πιο αποδοτική σε χαμηλές ταχύτητες. ☐ Σωστό ☐ Λάθος

Ατμοσφαιρική ρύπανση

14. Η ατμοσφαιρική ρύπανση από οχήματα με κινητήρα βενζίνης:

α. μπορεί να οφείλεται σε κακή ρύθμιση της ανάφλεξης ☐
β. δεν εξαρτάται από τις ρυθμίσεις του κινητήρα ☐
γ. δεν εξαρτάται από την ύπαρξη μόλυβδου στη βενζίνη ☐

15. Η ατμοσφαιρική ρύπανση από οχήματα με κινητήρα πετρελαίου:

α. εξαρτάται από τον τύπο του υγρού για το ψυγείο ☐
β. μηδενίζεται επιταχύνοντας ☐
γ. αυξάνεται εάν υπάρχει βλάβη στο σύστημα τροφοδοσίας ☐

16. Για να μειωθεί η ρύπανση του αέρα από τα βενζινοκίνητα οχήματα, πρέπει:

α. να ελέγχεται συχνά το σύστημα μετάδοσης ☐
β. να αποφεύγεται η παρατεταμένη χρήση χαμηλών σχέσεων στο κιβώτιο ταχυτήτων ☐
γ. να διατηρείται ζεστός ο κινητήρας, πατώντας το γκάζι επαναλαμβανόμενα, όντας σταματημένοι ☐

Θόρυβος

17. Ο θόρυβος που προκαλείται από τα οχήματα:

α. μειώνεται με την επιτάχυνση ☐
β. μειώνεται αν έχει καθαριστεί ο κινητήρας ☐
γ. μπορεί να μειωθεί με σωστή οδήγηση, αποφεύγοντας απότομα φρεναρίσματα και επιταχύνσεις ☐

18. Για την αποφυγή θορύβου, κατά τη διάρκεια της οδήγησης, θα πρέπει:

α. να αυξομειώνεται συνεχώς ταχύτητα με την ίδια σχέση στο κιβώτιο ταχυτήτων ☐
β. να γίνεται χρήση της κόρνας, μόνο σε περιπτώσεις κυκλοφοριακής συμφόρησης ☐
γ. να αποφεύγεται το απότομο φρενάρισμα, εάν δεν είναι απολύτως απαραίτητο ☐

Γενικής φύσης

19. Κατά την επιτάχυνση είναι καλύτερη:

α. γρήγορη επιτάχυνση μέχρι την επιθυμητή ταχύτητα ☐
β. σταδιακή επιτάχυνση μέχρι την επιθυμητή ταχύτητα ☐

20. Η κατανάλωση καυσίμου μπορεί να μειωθεί, με τακτικούς ελέγχους του οχήματος από μηχανικό ☐ Σωστό ☐ Λάθος

Γενικές πληροφορίες

Φύλο: ☐ Άρρεν ☐ Θήλυ **Ηλικία:** ☐ < 18 ☐ 18 – 24 ☐ 25 – 44 ☐ 45 – 64 ☐ > 65

Είσαι: ☐ Κάτοικος πόλης Ρεθύμνου ☐ Κάτοικος εκτός πόλης (σημειώστε κωμόπολη/χωριό)____________________

☐ Κάτοικος άλλης πόλης εκτός νομού Ρεθύμνου

Έχεις: ☐ Αυτοκίνητο ☐ Μηχανή/Σκούτερ ☐ Άλλο μηχανοκίνητο όχημα: __________________

Εάν θέλεις να λαμβάνεις πληροφορίες για μελλοντικές εκδηλώσεις του Εργαστηρίου Ανανεώσιμων και Βιώσιμων Ενεργειακών Συστημάτων του Πολυτεχνείου Κρήτης, σχετικές με τη βιώσιμη κινητικότητα και την οικολογική μετακίνηση, παρακαλούμε συμπλήρωσε το e-mail σου*:

E-mail: ____

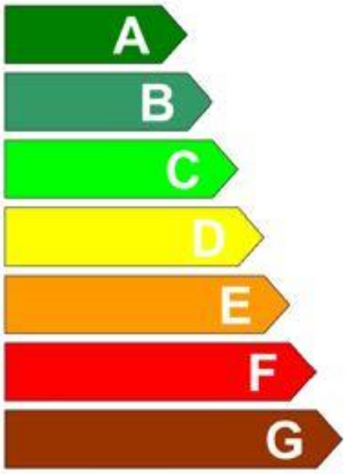
Ονοματεπώνυμο (προαιρετικά): ____

*Η επεξεργασία των προσωπικών σας δεδομένων γίνεται σύμφωνα με τον Γενικό Κανονισμό Προστασίας Προσωπικών Δεδομένων (GDPR) ΕΕ 2016/679 και την εν ισχύ εθνική νομοθεσία, όπως αυτά εκάστοτε τροποποιούνται . Τα προσωπικά σας δεδομένα δεν θα κοινοποιηθούν σε τρίτου. Θα χρησιμοποιηθούν αποκλειστικά για την αποστολή πληροφοριών για μελλοντικές δραστηριότητες του Εργαστηρίου Ανανεώσιμων και Βιώσιμων Ενεργειακών Συστημάτων του Πολυτεχνείου Κρήτης, ι σχετικές με τη βιώσιμη κινητικότητα και την οικολογική μετακίνηση. Μπορείτε οποιαδήποτε να επικοινωνήσετε μαζί μας, για να ζητήσετε την διαγραφή των προσωπικών σας δεδομένων από το αρχείο μας στη διεύθυνση (**destinations.tuc2@gmail.com**).

ΒΑΘΜΟΛΟΓΙΑ QUIZ ΟΙΚΟΛΟΓΙΚΗΣ ΟΔΗΓΗΣΗΣ

Με την οικολογική οδήγηση, εξοικονομούμε ενέργεια, χρήματα, προστατεύουμε το περιβάλλον και μειώνουμε την ηχορύπανση.

Για κάθε μία σωστή απάντηση, πρόσθεσε έναν πόντο. Υπολόγισε τους πόντους που συγκέντρωσες και δες σε ποια «ενεργειακή κατηγορία» οδηγού ανήκεις!



20 βαθμούς
17-19 βαθμούς
14-16 βαθμούς
11-13 βαθμούς
8-10 βαθμούς
5-7 βαθμούς
Κάτω από 4

Annex B

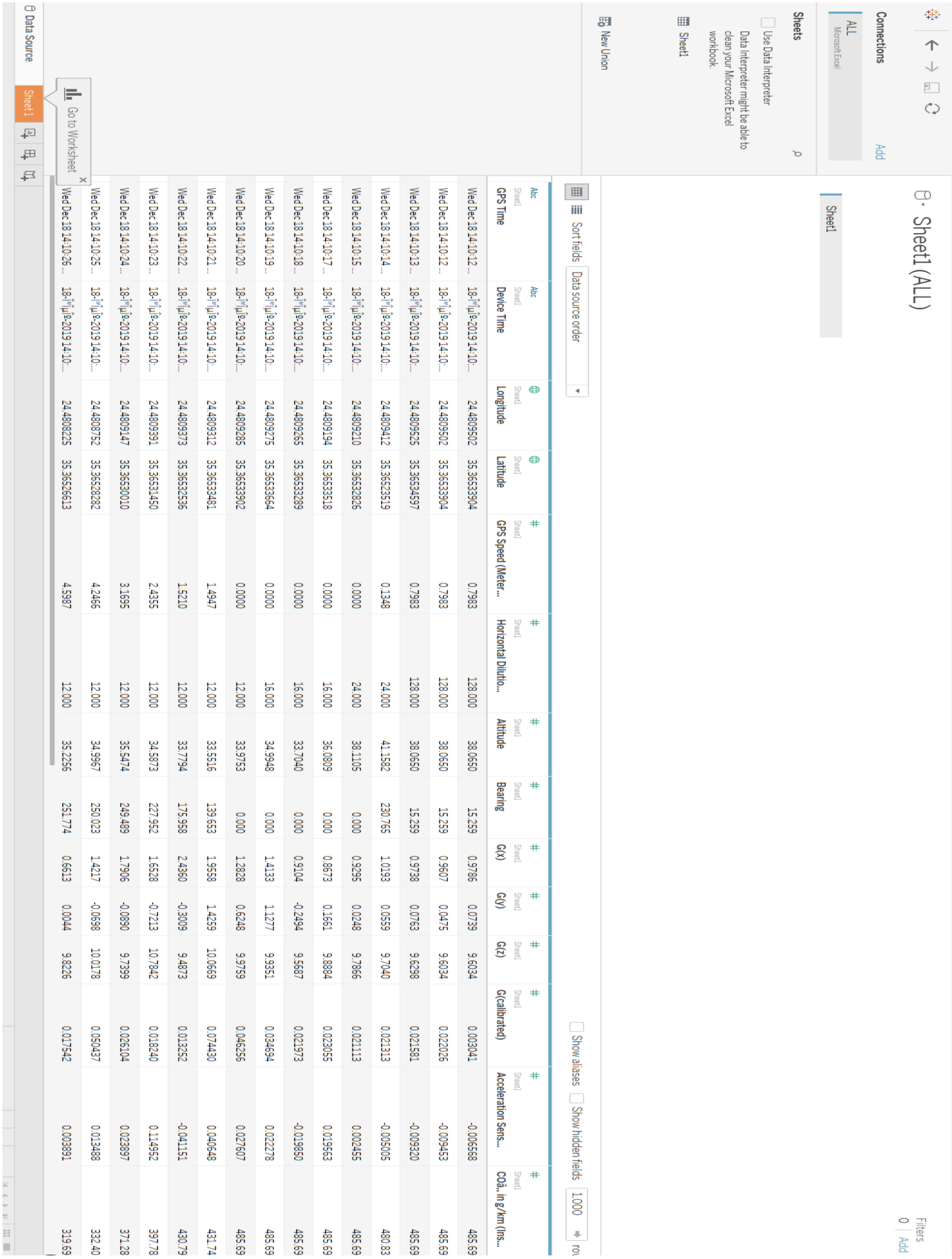


Figure B.20 Inserting the data into the Tableau Public software

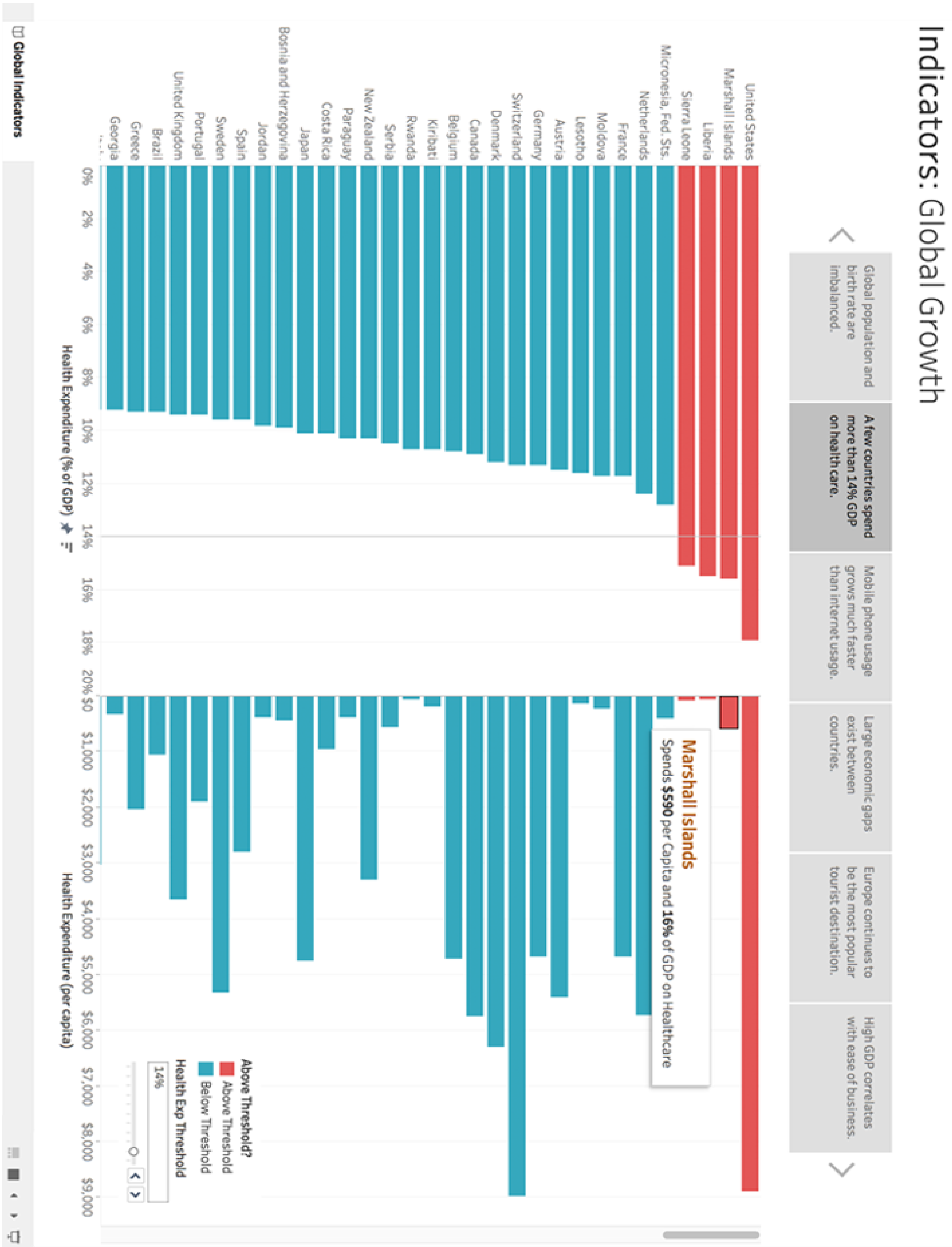


Figure B.21 Tableau Public example of visualization