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Proceedings of the 3rd International Conference on
ENERGY in TRANSPORTATION 2018
Athens, November 3, 2018

Foreword

I. Deligkiozi, D.A. Charalambopoulos

"ENERGY in TRANSPORTATION" expands the International Conference "ENVIRONMENT & ENERGY in SHIPS" and "GREEN TRANSPORTATION" that were held in 2015 & 2016 respectively, to include all modes of Transportation, Ship, Aviation and Land, both public and private. It brings together Engineers, Designers, Academics and Professionals of different disciplines and other stakeholders that contribute to and advance the state of art development within the transportation environment. "ENERGY in TRANSPORTATION" is an annual International Conference that took place for the fifth consecutive year. The 5th International Conference EinT2019 was organized by the ASHRAE Hellenic Chapter in collaboration with the Technical Chamber of Greece (TEE), the Hellenic Navy and the Attiko Metro. The event was held in Athens, Hellas on September 28, 2019. A total of 10 speakers from Egypt, Greece and the USA, presented 4 technical papers that are included in these Proceedings.

The program also included the following keynote and invited speakers:

- **Daryl Boyce**, ASHRAE president
- **Vice Admiral Nikolaos Tsounis HN**, Chief of the Hellenic Navy General Staff
- **Rear Admiral Georgios Bamblenis HN**, Director of Hellenic Navy Armaments Directorate
- **Dr. Costas A. BALARAS**, Director & Regional Chair, ASHRAE Region XIV, Greece
- **Georgios Pantelidis**, President, ASHRAE Hellenic Chapter, Hellas
- **Dimitris A. CHARALAMBOPOULOS**, ASHRAE Hellenic Chapter Board Member, ASHRAE Region XIV RMCR, ASHRAE Members Council, Greece

The Conference ended with a joint open discussion.

All the presentations and videos from the conference are available on the ASHRAE Hellenic Chapter's website (http://ashrae.gr/EinT2019.php).

We specially thank the speakers, the members of the Conference Scientific Committee, the numerous volunteers, the sponsors and the participants that made this a successful event.

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Developing an integrated environmental policy for ports using Multicriteria Decision Making Analysis

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ABSTRACT

In ports, many sectors, such as shipping, trucking, and passenger transport are active and can yield many positive effects on local social and economic spheres. The ever-increasing demand for maritime transport has caused chain reactions in port operation around the world. The primary effect of these changes is the continuous growth and development of ports in response to the new global trade. Globally, large ports, in an effort to meet modern demands, have adopted management standards that go beyond the national level and seek to keep up with standards set by European or other international organizations and countries. The ever-increasing demands on the speed, cost, quality and security of human and goods movement underscore the importance of modernizing and optimizing all port operations. In a general sense, a port can be considered competitive if it provides modern, fast and quality services to users at the lowest possible cost. Modern ports in their role as centers of world trade and economic development must be seen as key links within integrated and automated transport chains. Consequently, a port has a direct role to play in international trade, with a prerequisite, of course, of providing modern logistics services. Within the above context, the goal of this study is to present the main criteria for the assessment of the environmental footprint of ports and how this can be optimized with the implementation of certain key actions. The main objectives of the research are to promote an understanding of the term "green growth" to explore the different ways of achieving green growth, its key features as well as the established advantages and disadvantages of its implementation in various ports worldwide. Developing an integrated environmental policy and the choice of appropriate measures, in particular, is a complex process since there is a large number of available alternative actions for environmental management. Moreover, each measure/action presents various technical, economic, environmental indicators, the analysis of which can determine the degree of their implementation in a port operational development and infrastructure. It is, therefore, necessary, to adopt a reliable and scientifically documented approach for the comparative assessment. For the evaluation of the above factors, the multi-criteria decision making was used.

INTRODUCTION

Environment is a key concern in the sustainable development and prosperity of a society. In recent decades the role of sustainability in the development of national and international politics has substantial. The responsible use of energy resources, taking into account affordability environmental impacts is the main objective of energy policy. The environmental design of a port is a process of developing long-term strategies. In port design cases, decisions should be made, taking into account many parameters (Tsitoura et al 2016). On the other hand, not only land-based port facilities but also ships are a major source of pollution (Meyer et al, 2012; Song et al 2014; Dwarakish et al 2015). Taking into account technical, social and environmental parameters combined with the collection of data on vessel frequency, number of passengers and cargoes, an environmental design of a port can be implemented using different models. The need to incorporate several parameters into environmental design has led to the use of models focusing on the use of multi-criteria analysis methods. Maritime transport is the backbone of world trade and is at the heart of international transport networks. It is an important independent economic sector that creates employment, generates income and revenues and

crosses other sectors and activities horizontally. It is therefore obvious that maritime transport activities, and therefore ports play a key role in international trade and economic prosperity. Each port, whether commercial or passenger, is a link in the transport network of people, raw materials, goods and merchandise at local, national and global level. The ever-increasing demands on the volume, speed, cost, quality, and safety of maritime transport make ports, particularly commercial, of strategic importance from an economic and social point of view, giving them an important role in the design of economic policy (De Martino 2014). Ports worldwide are responsible for the significant proportion of greenhouse gas emissions due to the operation of several services (Borghesi et al, 2003). In this context, new methods and techniques have been developed to improve the environmental performance of a port towards the green port (Teerawattana et al, 2019). A green port is considered to be a port which is operated and organized based on the principles of sustainable development. A green port not only meets environmental requirements but provides satisfaction with significant economic benefits and income generation (Broman et al, 2017; Sifakis et al, 2019; Sifakis et al, 2019).

The main problem in a green port is to find a balance between the environmental impact of its operation and its economic benefits (Bergqvist et al, 2018). The point of balance is based on the combination of consumption of natural resources and the environment with economic aspirations, fulfilling the basic prerequisite that irreversible environmental changes will ever occur. The main objectives of a green port are to

- achieve good environmental quality and high economic efficiency,
- build environmentally friendly port facilities,
- ensure the overall harmonious and sustainable operation of the system fostered by society, the economy and the environment,
- and the establishment of the leading and competitive position of the harbor in modern transport, the supply chain, port services and the production system (Di Vaio et al, 2018).

Summing up, the concept of a green port integrates the principles of sustainable development into all activities related to the construction of port infrastructures and the operation of the port in order to increase the efficiency of resource utilization and thus to achieve the lowest possible emissions reducing the negative impact on the regional environment, ensuring the best possible environmental quality into the port area and achieving social economic growth of both the port and the surrounding region (Canbulat 2014). Many ports have started implementing solutions to improve their environmental footprint. Such actions include the use of renewable energy sources, smart grids, offshore electricity, etc. (Lättilä et al, 2013; Hiranandani 2014; Kotowska 2016). The main objective of this survey is to explore all the parameters in a port to ensure that the proposals that will be made are tangible, sustainable and have a positive impact on the port environment.

METHODOLOGY

The Environmental Impact Assessment process is a crucial requirement as it makes a significant contribution to protecting and preserving the natural and man-made environment (Saengsupavanich 2011). The environmental impact assessment is defined as a "tool used to identify the environmental, social and economic impacts of a project prior to decision-making. Its objective is to anticipate environmental impacts at an early stage of project design, to find ways and means to reduce adverse impacts, to shape projects that fit the local environment and to present forecasts and choices to decision-makers. It is important to note that the environmental impact assessment process is linked not only to environmental but also to economic benefits.

It is also the main basis for negotiation between investors, citizens and governmental authorities, the stakeholders involved in the impact assessment process. In addition, environment-related institutions often try to solve problems with technological means that require extensive use of natural resources and redistribution of wealth without knowing all the data. Against this background, taking into account the multiple uncertainties and complexities and the interconnected issues of sustainability and social justice, the need for more participatory forms of government becomes imperative. This need has led to extensive discussions on the importance of engaging in different disciplines such as political and social sciences, business research and the economic sciences as well as attempting to synthesize these discussions in an integrated methodological approach. An important tool for carrying out the environmental impact assessment process is multi-criteria analysis.

The Multi-Criteria Decision Analysis (MCDA) is a capable method to synthesize a large amount of information without altering the goals and preferences of the individual recipient of the decision. Its goal is to help make decisions rather than make the decision. At the same time, it is a methodological approach and a set of techniques aimed at prioritizing different alternatives from best to worse. But the basic assumption of this approach is that decision-makers must be consistent in decision-making and, as far as possible, seek to not make conflicting decisions.

According to the aforementioned, the importance of choosing those criteria on the basis of which the evaluation and, by extension, the hierarchy of measures will be made is immediately understood. The following factors were taken under consideration for the selection of the criteria: There are three pillars of the concept of sustainability and their evolution: environmental, economic and social (Clune et al, 2018). In order to evaluate the objectives and the individual criteria, a questionnaire was established which has been distributed to the individuals that participated in the survey. In particular, the questionnaire was answered by 50 participants. The replies to the questionnaire were collected in a capable, for analysis, format. The criteria of the statistical analysis **are presented in depth in Table 1**.

The selection of the multiple criteria for each of the above objectives was made after a bibliographic review. In the end, 13 criteria were met and, based on a questionnaire for the social partners' opinion, the weights were selected for each criterion for the final rating and hierarchy of measures. The environmental dimension of sustainability includes indicators for reducing energy consumption and environmental pollution. The economic dimension of sustainability includes indicators, such as tourist movement, tourist services, local regional economy, and competitiveness. The social dimension of sustainability includes indicators on Satisfaction of Interested Parties with the services provided by the port, Staff and Infrastructure Security, Employment of Staff and Security of Services. Additionally, indicators were provided to evaluate the technological dimension of a port by looking at the following parameters: user-friendly technological applications, technology efficiency and maturity of the technology.

Table 1. Initial results of the statistical analysis

Category	Criteria
Environment	Energy, environmental pollution
Society	Tourist movement, occupation, competitiveness, satisfaction of the stakeholders, Staff/infrastructure security, security of the services provided, tourist services
Economy	Local economy, staff employment
Technology	Maturity of technology, User-friendly technological applications

The survey sample was administered to a wide range of professionals employed directly or indirectly in port facilities. In particular, responses were collected from different categories of professions such as fishermen, shipmasters, shipping companies, dockers. Responses were also received from various departments such as Coast Guard, Customs, and Port Authority. The involvement of residents and merchants in the area was also important. The details of the sample of the respondent **are presented, in depth, in** Error! Reference source not found..

Table 2. Details of the sample of respondents

Groups	Abbreviations	Stakeholders
Academic	Academic	Technical University of Crete, Mediterranean Agronomic Institute of Chania (MAICh)
Employees	Employees	Dockers, Fishermen, Marine engineering, Port Facility Security Officer
Government	Govern	Coast Guard Authority, Customs, Police
Local authority	Local auth	Municipality, Harbour Management Organisation
Local Community	Loc com	Residents, Merchants, Students
Private sector	Priv Sec	Crane Companies, Anti pollution companies, Load transportation companies
Ship operator	Ship Oper	Shipping lines, Shipping Agencies, Crew members
Suppliers	Suppliers	Fuel suppliers, Ship Chandlers
Touristic sector	Tour Sector	Travel agencies, Tourists
Transport operator	Trans Oper	Private bus, TAXI drivers

The case study of this research work was about Souda Port, which is located in the northern part of the Prefecture of Chania. The port of Souda constitutes the harbor gate of Western Crete and serves both the prefecture of Chania and a large part of the Prefecture of Rethymno. The port currently occupies an area of 161.4 hectares, including the newly constructed "ADRIA" Pier at the eastern end of the harbor. Due to its strategic position, it has always been of great importance for the island of Crete. It is the second largest port of Crete, after Heraklion, and serves domestic and foreign ships. Today, it is a continuously growing port, having a daily connection with the port of Piraeus and other ports of the Greek islands. It also serves many cruise ships that transport visitors and tourists to the Greek islands and contributes decisively to the commercial, tourist and economic development of the Prefecture of Chania.

The main areas of the port are (a) the passenger Port Area and (b) the Commercial Port area, **as shown in** Error! Reference source not found..

Picture 1 Port of Souda

The entire passenger traffic and part of the freight are being served by the passenger part of the port. On the other hand, the commercial part of the port, serves the handling of general merchandise, dry bulk goods (cereals and other products (flour, feed) as well as liquid and hazardous cargoes, including open-air storage and cargo storage areas and open-air conveyor belts. The main sources of pollution in the port area are the operation of the port, the Naval Base and the road traffic as they coexist in a relatively limited area on the Souda coast. Other activities such as agricultural/commercial activities do not have a great impact on the environment.

RESULTS

The selected criteria were evaluated according to their significance in the selection of appropriate mobility policies and their ranking provided required data for the calculation of corresponding weights for the analysis. As described above, each participant was invited to complete a classification table, indicating his/her order of preference of the criteria, from the most important (1) to the least one (10). The participants were encouraged to insert more than one criteria in the same row if they consider that various specific criteria are equally important and therefore cannot be differently ranked. For each response, the relative weights were calculated, while the weight of each criterion per stakeholder group was calculated as the average value of the relative weights of the specific group actors involved. Error! Reference source not found. presents the process for the calculation of the relative weights for each participant of a specific group and breaks down the results by the category of the respondents. Table 3 also shows the average percentage for each criterion. The average was calculated after having taken into account the weights of each group of respondents. This calculation was made in order to examine the port from a collective point of view of all the actors involved as a single system.

Table 3. Relative weights of each participant and each factor

Groups	Academic	Employees	Government	Local authorities	Local community	Private sector	Ship operators	Suppliers	Tourism sector	Transportation operators	Total (%)
Environmental pollution	10.5	9	8.6	7.2	8.8	9.4	10.4	10	8.9	8.5	9.1
Energy	10	8.8	7.3	7.4	8.1	8.5	9.3	8.9	8	6.8	8.3
Competitiveness	8.6	7.6	7.3	8.5	7.1	7.7	7.7	7.6	8	7,9	7.8
Effectiveness	8.4	6.4	7.9	7.4	6.9	6.6	5.9	5.8	6.5	6,8	6.9
Local / Regional Economy	8.1	7.3	7.3	8.8	7.1	7.2	8.5	7.9	7.6	7,6	7.7
Staff/Infrastructure security	8.1	8.9	7.8	8.7	7.8	8.8	8.8	9.6	8.9	8,2	8.6
User friendly technological applications	7.3	6.4	8.4	7.4	8.1	7.5	5.6	6.2	7.1	7,9	7.2
Security of the services provided	7.1	7.6	8.1	7.7	7.4	8.5	8.8	8.6	8.3	7,9	8
Tourist services	6.8	7.9	7.9	7.4	8.1	7.7	8.2	8.2	8	8.6	7.9
Staff employment	6.8	7.8	7.6	6.6	7.8	6.8	7.2	6.5	7	6,5	7.1
Maturity of technology	6.8	6.1	8.1	7.6	7.4	6.2	4.5	5.2	6.5	6,8	6.5
Satisfaction of interested parties with the services offered by the port	6.3	7.9	6.8	8.3	8	7.9	7.7	7.9	8	8,6	7.7

In Figure 1, the cumulative result that arises after having collected all the results from all categories is observed.

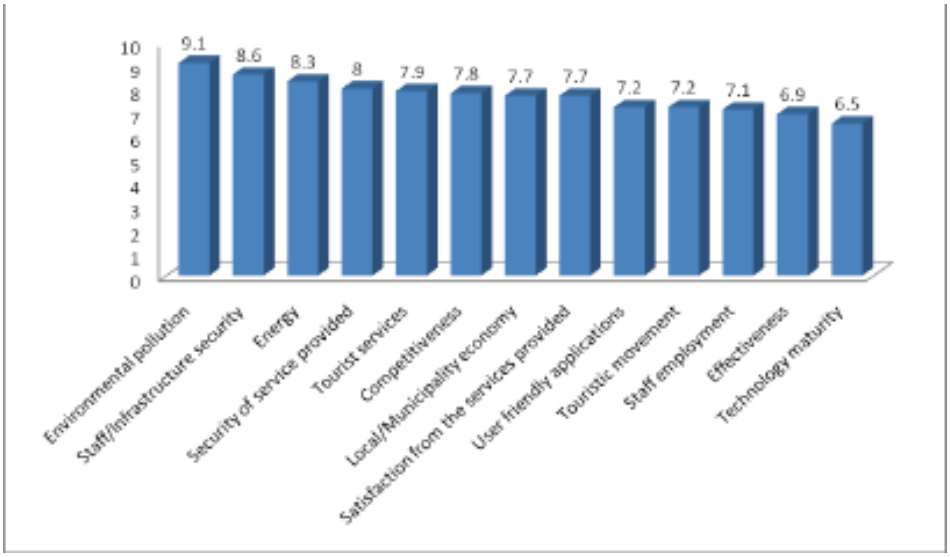

Figure 1 Cumulative results of all the observed categories

The analysis of **Table 3** showed that 9 out of 10 rated environmental pollution with a score of over 8.5. 5 out of 10 gave the same score to personnel security, 4 out of 10 energy and 3 out of 10 to the safety of the services provided. These results are also reflected **in Figure 1** where it is observed that these factors are rated at the first places. From the above, it is evident that in the case of the Souda port the most important priorities are the following: Environmental pollution, staff safety, energy, security of the service. Compared to the research priorities (environmental pollution, energy), it can be observed that the key priorities of this specific research (environmental pollution and energy) coincide with the key priorities of the European Sea Ports Organisation's (ESPO) research (**Figure 2**), making this research, credible.

Figure 2 Top 10 environmental priorities of European ports for 2018 (ESPO)

Another element that is of great importance is the criterion with the maximum and minimum scores for each group individually which are presented **in Table 4**.

Table 4. Maximum and minimum scores for each group

Stakeholder	Max	Min
Academic	Environmental pollution	Touristic movement
Employees	Environmental pollution	Technology maturity
Government	Environmental pollution	Satisfaction of serviced provided
Local authorities	Local economy	Staff employment
Local community	Environmental pollution	Effectiveness
Private sector	Environmental pollution	Maturity of technology
Ship operators	Environmental pollution	Maturity of technology
Suppliers	Environmental pollution	Maturity of technology
Tourism sector	Environmental pollution	Maturity of technology
Transportation operators	Tourist services	Staff employment

It is observed that seven out of ten groups have decided as the most important criterion, environmental pollution.

CONCLUSIONS

Concluding, the goal of this study was to present the main criteria for the assessment of the environmental footprint of ports and how this can be optimized with the implementation of certain key actions. The main objectives of the research were to promote an understanding of the term "green growth", to explore the different ways of achieving green growth, its key features, and the established advantages and disadvantages of its implementation in various ports worldwide, as well. This research work attempted to review the basic Multi-criteria Analysis techniques and their application to an environmental management problem in order to identify its environmental, social and economic impacts prior to decision-making. The problem addressed, is the improvement of the environmental footprint of the port of Souda by asking the priorities of each stakeholder in order to rank them.

The results of the sample revealed that the top priority for almost each and every stakeholder, was the environmental pollution of the port and this enhances the prospect of green growth and the establishment of green ports. Various other major priorities of port's stakeholders, were the overall security in the port area, the energy efficiency, the attractiveness of the port facilities and services for the tourists, and the competitiveness among other ports. On the other hand, the least important priorities for the port stakeholders were the effectiveness of the port and the technological maturity of its infrastructures. Last but not least, local authorities seem to prefer the buoyant of the local economy and this can be credited to their specific interests.

Furthermore, the findings of this study coincide with the ESPO's ones regarding various, same or almost same, criteria and the most important of them is that both types of research point out environmental pollution (air quality) and energy efficiency as one of the top priorities of port authorities and stakeholders. Combining these two, great improvements can be achieved into port areas, reducing their environmental footprint. There are specific research works that have tested this prospect and showed that green ports or, nearly Zero Energy ports, is not only feasible but credible, as well.

Thus, this research, taking into account the need of all actors, attempted to model the decision criteria on the three main axes, which are the levels of sustainability as mentioned before. However, before the final decision, the agencies should thoroughly examine the implementation of the research outcome in the light of its entrepreneurial action, taking into account all the parameters.

This study, although it was based on a well-known methodology, presented some challenges according to the findings. One of the main challenges was the collection of questionnaires, which were sent to several stakeholders for the evaluation of the criteria. Some of the actors contacted were more easily accessible and cooperative. A general comment received during this process was that the questionnaire was simple to complete but thorough enough to provide all the vital, for the research, information. The questionnaire's form was a key motivational factor for the successful collection of the required input. Although the abovementioned challenge, regarding delayed responses, was faced for all stakeholder groups, certain group categories were even more challenging to access, thus risking the adequate representation of the groups.

European seaports are a vital factor for the European economy and economic growth, as a large proportion of goods exported or imported into the European Union are transported through them. At the same time, the challenges they face are increasing rapidly, as container traffic is on a significant upward course. In addition, port management bodies have to comply with increasingly stringent international environmental regulations and social perceptions of sustainability. Against this background, there is an urgent need for a strategy for the sustainable development of ports and for their sustainable interconnection with the urban environment, thus enhancing the mutually beneficial relationship with the city. The main future goal of the exploration may be to develop a strategic and innovative framework of new port technologies and measures to address imminent and future capacity, increasing traffic and environmental challenges.

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Design of an Eco- Racing Yacht - A Naval Approach

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ABSTRACT

The aim of this paper was to investigate the employment of eco-friendly modern design solutions in the cruising yacht industry, in order to achieve low emissions and access to environmentally restricted marine zones, and the interaction of the design requirements with efficient and functional space planning. After thorough research of various hull geometries and their characteristics, we settled into the concept of a racing yacht. Regarding the geometry, we chose a yacht design because of the particular benefits that this geometry presents on the subjects of stability, low draft, minimal wetted surface and consequently lower drag forces. Concerning the sailing system, we designed it around 11 m. Further energy can be accumulated from the solar panels designed into the sundeck, while the dedicated sky sail can be used in certain wind conditions to reduce further the energy consumption of the yacht. Both the hull geometry and the photovoltaic (PV) units and solutions were then introduced into the design of a prototype yacht designed to host four guests and crew and perform Mediterranean voyages. The environment design of the hull and sails used as guidelines in order to produce a 7.20 m yacht that is sufficient to travel and racing.

INTRODUCTION

For centuries Naval Architecture was an art. The Lines Plan and the Half Model, for centuries, provided an efficient method of accurately representing the ship, allowing measurements to be taken for the full size ship and calculations possible. Design remained the same until the computer became a practical possibility. This allowed the designer to model ships accurately in three dimensions, without the need of the skills required to make a half model and removing the two dimensional failings of the lines plan. Mathematical curve and surface generation techniques also developed (Mazarakos, 2014). Today the computer is a prerequisite for the naval architect.

Once generation techniques for designing hulls became possible, some naval architects thought about the process of design. They could see the large amounts of time required for modifying and fairing the shapes of vessels so that predefined goals, factors of design and coefficient could be met. Techniques were developed that created ships hulls, which allowed hulls to be rapidly created and more complex design properties such as resistance and motions could be analyzed in a shorter time. Despite the development of these techniques, however, the main method of acquiring a fair hull is still by manual modification, performed by the naval architect. The yacht design process is similar to that of ships, but in yachts, a greater variety of parameters and goals are required to complete a successful design. The vast majority of recent publications relating to yacht design come to it from an engineering perspective, based on academic research rather than practical experience and embodied, full-scale productions (Larson and Eliasson, 2000, Fossati, 2010, Marshall, 1979).

Current yacht design literature is lacking in works by practicing yacht designers, describing actual design methods and processes, perhaps because of concerns about commercial sensitivity in a competitive environment. Another aspect restricting the availability of detailed explanations of design theory is the inability of many designers to articulate their tacit knowledge in an explicit form (Schön, 1988). Some literature has explored the influence of art in yacht design - that is, the use of more intuitive processes and the concept of the "designer's eye" for what looks right - but little research exists which explores the interrelation of art and science in this field. The process of design is strongly identified throughout these texts in the contexts of engineering design, design method of yacht design.

BASIC DESIGN PARAMETERS

The theoretical framework is based on the action research model described by Zuber-Skerrit (2001). This was in

keeping with the concept of yacht design utilizing a design spiral, in which each aspect of the design is explored and refined in turn, before a further iteration is developed, explored and further refined. The lack of a complete, recognized methodology for designing racing yachts has resulted in an environment which does not foster innovation, relying instead on engineering techniques which impose limitations on the design process. Designers are also limited to some extent by tradition - following what has gone before - as well as being hampered by class and rating rules. In this paper explored and defined a new methodological framework, blending the empirical knowledge obtained through scientific techniques with experiential wisdom and artistic input.

Concept development

The development of the eco- racing yacht first centered around the overall size of the boat. The main drivers here were cost and achievability issues, including time to design and build and the cost of design and construction. We settled on an overall length (L_{OA}) of 7.2 m for several reasons:

- Affordability compared to a 12 m or larger yacht
- Affordability of campaigning, marina storage and ongoing maintenance
- Established sailing divisions/records for yachts 9 m and under
- Ability for the boat to be transported in a 12 m shipping container
- Suitable size for sailing with a crew of no more than six, and as few as two
- Large enough to safely compete in longer-distance.

Other defining attribute was the boat's maximum beam. We wanted the boat to have a generous beam to gain the righting moment required to be competitive and to enable short-handed sailing without the need for a high ballast ratio and increased displacement. However, as transportability by container was a key goal, this applied a restriction on the beam. We resolved that it would need to have the maximum beam possible which would still enable containerization. To ascertain this, we drew up a representation of the inside dimension of a container door in CAD and used this to experiment with various cross-sections through a draft yacht model. We found a maximum beam of approximately 2.5 m and fit the boat into the container.

Hull and deck design

Within the parameters of maximum length and beam, section shape was primarily driven by the need to maximize form stability and produce a hull that maintains a high prismatic coefficient when heeled. Wetted surface area is a consideration in any yacht design. With the forward sections, the aim was to achieve a powerful shape that would provide good lift for reaching and running conditions, while not being so full that the boat would slam excessively when sailing upwind in a seaway. These elements are intrinsically linked and variation to any of them could only be made with consideration of the effect the alteration would have on the other elements that define the hull form. Given the desired characteristics we set the initial prismatic coefficient (Cp) at 0.594.

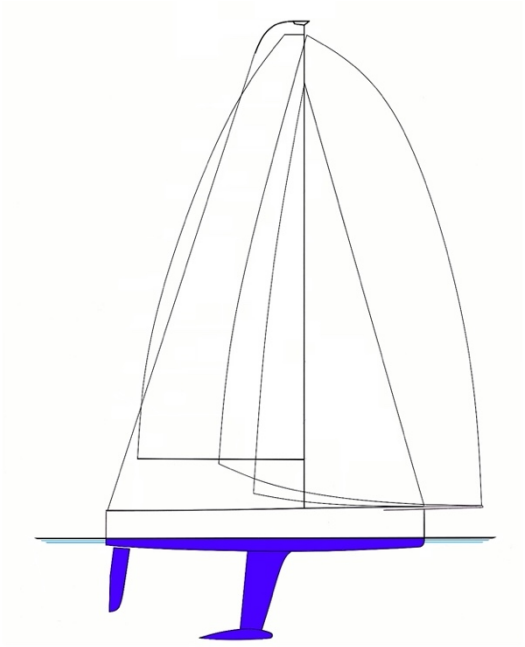

Figure 1 Preliminary concept drawing of the 7.2 m racing yacht.

Weight and balance

As part of the design refinement process and action research spiral, we set up a spreadsheet to develop a detailed weight study for the boat. Every component was weighed as it was built and its longitudinal center of gravity (LCG), transverse centers of gravity (TCG) and vertical center of gravity (VCG) considered and updated on the spreadsheet to ensure the finished boat would end up floating correctly, and that any discrepancies from the original weight study could be accommodated where possible in the ongoing construction. Although it is possible to adjust the amount of ballast in the keel to compensate for minor discrepancies, it is essential to get the weight study as accurate as possible before the final design of the hull is committed to building, as increasing any weights would likely result in a drop in stability and have a negative impact on performance and handling characteristics.

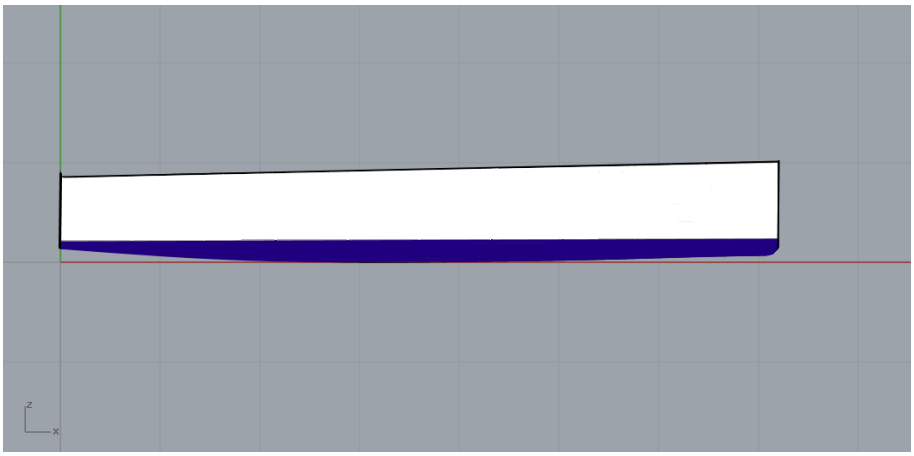

Figure 2 Draft lines plan for the 7.2 m yacht.

Deck design

Having drawn several iterations of draft plans for the hull, we had defined the sheer line, deck line, stem and

transom profile. These would not be able to change once the deck was built. As the deck is the second largest structure next to the hull, it gives a good gauge of the weight per square meter of the chosen construction method. Building the deck first allowed us the opportunity to update the weight study for the final hull lines drawing before committing to the hull shape. The placement of the yacht's engine also impacted on the deck and cockpit layout.

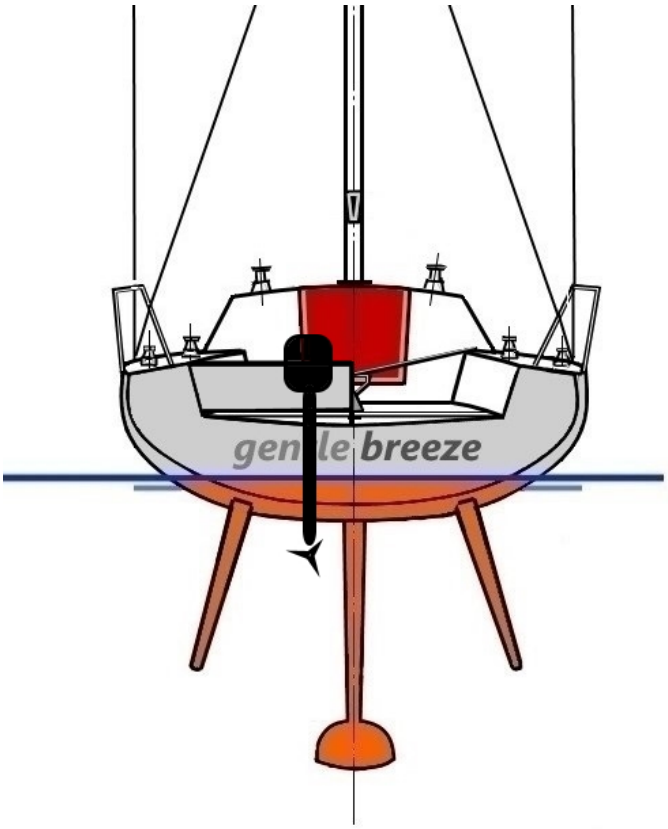

Figure 3 Placement of the yacht's engine.

Rig and sails

Sail plan

The sail area has been established based on the parametric study, in order to achieve sensible design ratios for a racing yacht (Misthos, 2019). The amount of sail area is quite large in order to maximize the light winds performance, and can always be reduced by reefing in stronger winds. The rise in center of effort and the inherent increase in heeling arm are not a problem in the light wind conditions for which the vessel is designed. In addition, the sail area being higher up it will be less affected by the wind strain and will create a larger wind shadow on the leeward boats (Ward, 2009).

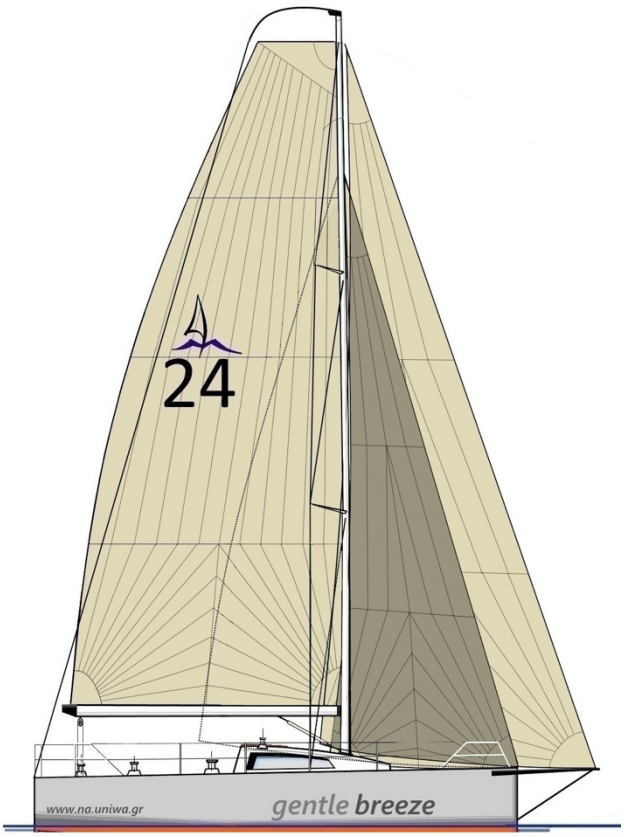

Figure 4 Upwind sail plan (full sail).

Backstays

Although the spreader rake is adequate to support the mast in most conditions, two exceptions to this were identified. Firstly, when running downwind under masthead gennaker in apparent wind above 15 knots there is potential for the rig to be overloaded. Sea state also has a big effect on this, as when the boat runs into the back of a wave and decelerates, a considerable load increase is transmitted through the rig. As wind speed and wave interference increase, the loads generated increase also. As noted by Larsson (2000), this is something which can't accurately be calculated or modelled. As the boat is intended to excel in such conditions, it was important that the rig be set up to take these worst load cases into account, so the crew wouldn't be forced into reducing sail area and therefore performance at these times.).

Figure 5 Sail plan with the addition of downwind sails.

HYDROSTATICS

Yachts are designed to be utilized in a dynamic medium, and thus as subject to three-dimensional motion. The motions (or six degrees of freedom, dof) to be considered are back and forth (surge), left and right (sway), up and down (heave), and rotation around these axes (pitch, yaw and roll).

The method used by Mazarakos, (2014) for generating ships hulls is similar to most other methods. Parameters are used as an input, to generate the shape of the hull. The parameters are:

- Primary Dimensions - Length, Beam, Draught and Depth.
- Block Coefficient and Longitudinal Centre of Buoyancy
- Sectional Area Curve
- Midship Section Coefficient
- Bow Profile
- Stern Profile
- Aft Control Section
- Shape Coefficient (A coefficient describing how similar the section is to 'U' or 'V' shapes)
- Functions of Volume and Volume Moments

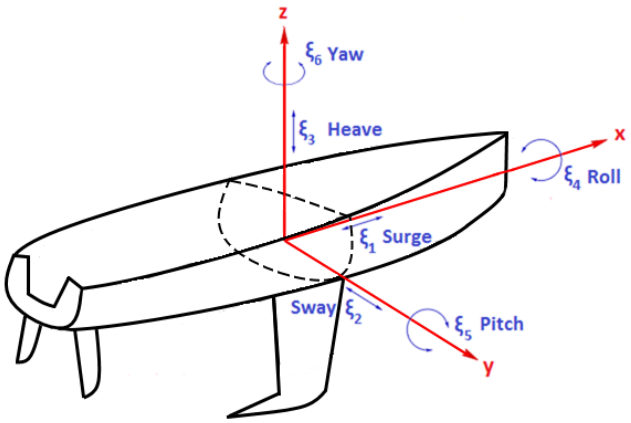

Figure 6 The motions of a yacht (surge, sway, heave, pitch, yaw and roll).

The study is primarily concerned with obtaining for a hull form, the correct Block coefficient and longitudinal center of buoyancy.

All the geometric properties of a ship as a function of mean draft have been computed and put into a single graph, called the "curves of form." Each ship has unique curves of form. There are also tables with the same information which are called the tabular curves of form (Mazarakos, 2014).

The following is a list of each characteristic found on the "curves of form" with a brief explanation of its meaning.

Displacement: is the weight of the water displaced by the ship for a given draft, assuming the ship is in salt water with a density of 1025kg/m^3. For a freely floating ship in salt water this is numerically equal to the weight of the ship.

LCB stands for the longitudinal center of buoyancy, which is the distance in m from the longitudinal reference position to the center of buoyancy. The reference position could be the FP or midships.

TPI stands for tons per cm immersion, or sometimes just called immersion. TPI is defined as the tons required obtaining one cm of parallel sinkage in salt water. Parallel sinkage is when the ship changes it's forward and after drafts by the same amount so that no change in trim occurs.

WPA or Awp stands for the water plane area. The units of WPA are m^2.

LCF is the longitudinal center of flotation, which is the distance in m from the longitudinal reference to the center of flotation. The reference position could be the FP or midships.

KM_L stands for the distance in m from the keel to the longitudinal metacenter. For now, just assume the metacenter is a convenient reference point vertically above the keel of the ship for naval architecture calculations.

KM_T stands for the distance in feet from the keel to the transverse metacenter.

Table 1. Basic Hydrostatic Parameters

Symbol	Value	Dimension
Displacement	1266	kg

LCB	3.161	m
LCF	2.924	m
VCB	0.124	m
WPA	9.578	m^2
KM_L	4.736	m
KM_T	22.328	m
C_B	0.447	-
C_P	0.594	-
C_{WP}	0.703	-

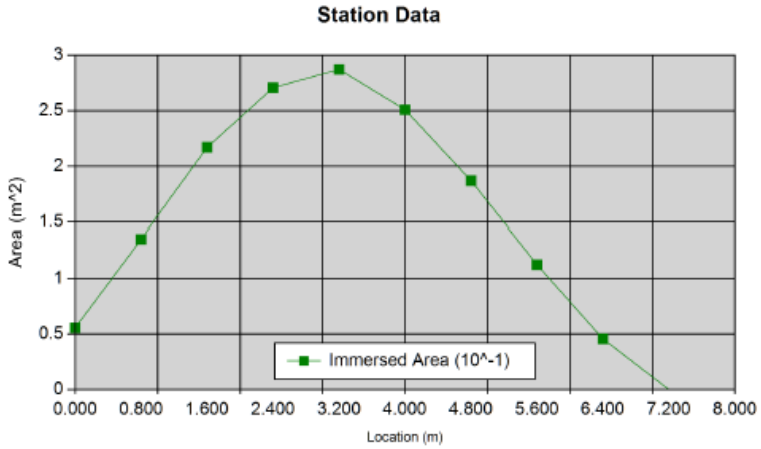

Figure 7 Preliminary Hydrostatic calculations - Station data.

ECO PROCEDURE

Electric propulsion

To reflect the ecological engagement, a fully electric propulsion system has been designed as an alternative to conventional diesel considering 1.1kW sail drive with 6kg Li-Ion batteries (achieving a similar range as the diesel engine). The on-board computer calculates the remaining range constantly, by linking the motor's consumption data with the charging level of the batteries, and the speed over the ground from the GPS. This allows the user to read the remaining range in real time from the motor display. This represents a small weight saving, enables to gain accommodation space due to the much smaller size engine; not to mention the fact that a 100% ecofriendly boat would be achieved.

Note that the hybrid option has also been considered, but in this instance turned out to be the heaviest and most expensive, and has therefore been abandoned.

Fire

The fire protection has been design to comply with the ISO 9094-1, also taking into account the ISAF, SOLAS and RYA recommendations.

Solar power sources

The on board photovoltaic cells will cover approximately 10 square meters of deck space and produce 1.352 kW to reduce fuel consumption, assume hotel load or stored as potential energy. Flex panels are beautiful, light and flexible. The flex panels generate energy silently and even in low-light conditions. Also flex panels have been tested under the toughest conditions.

Resistance to salt water and adverse weather conditions, along with lightness and design make them perfect for super yacht applications.

Figure 8 The invisible solar panel is a flexible 104 watt panel that can be integrated with a wooden deck. Photo Voltaic Cells - 10 square meters available space equal to 13 panels x 104 watts = 1.352 kW, and Optional Thermal Panels.

CONCLUSIONS

The development of the 7.2 m eco racing yacht provided a platform for the exploration of the inter-relationship of art and science in the practice of yacht design. Having considered the existing research and conventional wisdom that inform current design practice in this field, the complex journey of designing this new yacht took place, utilizing an action research model to establish a design concept and explore and refine aspects of it according to the three key considerations of accessibility, performance and handling characteristics. The design journey underscored the need to observe and reflect, to consider conventional wisdom and explore ways of expanding it, drawing on a balance of science (mathematical- and computer-driven processes) and art (intuition, past experience and the "designer's eye").

The action research method and use of a design spiral methodology proved highly successful in the development of the 7.2 m eco racing yacht. Focusing on the key considerations mentioned above, each aspect of the design, including the overall look (aesthetics), construction methods, hull and deck design, keel and appendages, and rig and sail design, was examined and developed using the process of planning, acting, observing and reflecting, leading on to the next iteration of each aspect and its development.

The resulting design is an aesthetically pleasing, modern-looking yacht which is cost-effective to build and campaign, and able to be transported by container, thus fulfilling the criterion of accessibility. On-the-water experience has also proved that yacht's positive handling characteristics, showing it to be an easy and comfortable boat to sail, with no discernable vices - the result of the careful consideration of the design of the hull shape and deck layout. The major design challenge here was to develop a yacht which not only looked fast but went fast, and vice versa.

On the luxury yachts today, the owners are packing the yachts full with all necessary and unnecessary items, which need to get better selected in terms of the weight issue on electric driven vessels. Owners and crew need to be more ecological with selection and use of HVAC systems. Europeans are more sensitive to energy consumption HVAC systems; in the US, people very often are freezing down their yachts so that you have to wear a jacket (even in high summer) when you enter the cabins. We can see the change of the mentality slowly especially with e-car drivers, where they are using very little AC to extend the range of the car.

Finally, at this moment, an experimentally campaign is conducted using a scale model (1:100) of this yacht in the laboratory wave basin, at the Department of Naval Architecture, University of West Attica/Athens, Greece. The wave basin measures 11 m x 1.2 m in size and the water depth used for the experiment is 0.6 m. The wave basin is equipped with a wave maker. The wave maker is capable of generating harmonic waves. The wave basin is fitted with wave absorber on the other side to reduce reflection. Water depth of 0.6 m is maintained constantly throughout the experimental investigation. A characteristic Fig. gives the construction of the model.

Figure 9 Scale design of the eco racing yacht.

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Sustainable Transportation Planning and Traffic Noise in Urban Environment: Case Survey in a Typical Mid-Sized Greek City

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ABSTRACT

Traffic noise is and important environmental health concern affecting public health and wellbeing of exposed citizens. Use of sustainable transport modes can be the solution in order to reduce the level of traffic noise in urban areas. This paper examines the relationship between sustainable transportation and reduction of perceived level of traffic noise in the city of Karditsa, a typical mid-sized Greek city. The research was based on a questionnaire survey conducted on a random sample of 200 participants through personal interviews in the year 2016. The questionnaire was formed of 18 questions divided into two parts. In the first part (questions 1÷6), the participants stated their demographic data and personal income comparing the years 2008 (before the economic crisis in Greece) and the year 2016 (economic crisis in progress). In the second part (questions 7÷18), the participants stated the change of perceived level of traffic noise in the city of Karditsa comparing the years 2008 and 2016, the influence of traffic noise in route and transport mode choice and their willingness to increase walking and bicycling due to the reduction of traffic noise. Furthermore, they stated the perceived level of traffic noise in the street of their residence during day and night time. Moreover, they stated their awareness of traffic noise negative impacts on public health and their willingness to change their residential area for a quieter but more expensive one. Finally, they stated their awareness of the sustainable transport modes positive impacts on traffic noise reduction and their willingness to pay an additional tax in order to fund relative projects for sustainable transportation and reduction of traffic noise. The recovery of Greek economy from economic crisis should not be an excuse to raise the use of private vehicles but an opportunity to change commuters travel behaviour in urban areas and promote sustainable transport modes with relative societal, environmental and economic benefits.

INTRODUCTION

Traffic noise is an important environmental health concern affecting public health and wellbeing of exposed citizens. Human exposure to noise from transport can lead to annoyance, stress, sleep disturbance and related increases in the risk of hypertension and cardiovascular disease. Sustainable transport modes provide citizens the ability to travel in urban areas using their physical power in order to walk or bike and therefore reduce the level of traffic noise. This paper examines the relationship between sustainable transportation and reduction of perceived level of traffic noise in the city of Karditsa, a typical mid-sized Greek city. The research was based on a questionnaire survey conducted on a random sample of 200 participants through personal interviews in the year 2016. The recovery of Greek economy from economic crisis is an opportunity to change commuters travel behaviour in urban areas and promote sustainable transport modes with relative societal, environmental and economic benefits.

LITERATURE REVIEW

World Health Organization considers noise as the third most hazardous type of pollution, following air and water pollution in big cities (WHO, 2005). Serious concerns about health impacts and annoyance caused by environmental noise are growing among both the general public and policy makers in Europe. Extensive urbanization and increase of road transport define the main driving forces for the environmental noise exposure of the population. Traffic noise mitigation measures have to be introduced especially in urban motorways in order to enhance the rehabilitation of the acoustic

environment. However, it is importation to notice that environmental noise protection is not only a matter of infrastructure but also a matter of "Ecological driving" (Vogiatzis, 2011). The World Health Organization reported that for road traffic noise, the dataset covers the exposure distribution in approximately 20% of the total EU population as of January 2010 (WHO, 2011). The European Environmental Agency estimated that environmental noise causes at least 16,600 cases of premature death in Europe each year, with almost 32 million adults annoyed by it and a further 13 million suffering from sleep disturbance. In addition, an estimated 13,000 school children suffer learning impairment due to the effects of noise near to major airports in Europe. European Union adopted the Directive 2002/49/EC relative to the evaluation of ambient outdoor environmental noise. Surveillance of ambient community noise is now mandatory for European cities with population over 250,000. As a result, several cities have established noise surveillance programs and set goals to reduce the size of the population exposed to high noise levels. Reducing traffic noise at the source will require new road standards and lower engine noise levels. Noise abatement programs have an environmental justice dimension and need to target the at-risk population (Moudon, 2009).

Traffic related noise is becoming the most health-threatening environmental stressors in Europe, and more people are exposed to traffic-related noise than to any other environmental stressors. Excessive exposure to noise could be considered as a health risk in a way that noise may contribute to the development and aggravation of stress related conditions such as high blood pressure, coronary disease, ulcers and migraine headaches. In recent years the importance of urban form on sustainable development has been recognized. Urban geometry and urban land-use pattern are two basic characteristics of urban form. They fundamentally determine transportation demands, which directly affect traffic noise and air pollution. Some researchers have studied the spatial relationship among urban form, traffic volume and traffic noise (Geerlings and Stead, 2003). Other researchers have investigated the influences of existing urban forms on vehicle transport and pedestrian exposure to traffic noise (Sheng and Tang, 2011). Furthermore, researchers have used the Geographic Information System (GIS) as a tool in spatial analysis and modeling in order to estimate the level of noise in urban areas (Moragues and Alcaide, 1996).

Motorized transportation is mainly responsible for urban traffic noise. Mopeds, scooters and motorbikes are in large use in the Southern European countries of Spain, Italy and Greece. In these countries the possibility of driving for a large part of the year under good climate conditions, together with the need to overcome the problem of city traffic congestion, makes the use of "power two vehicles" (PTW) extremely attractive. PTW produce additional traffic noise which is especially annoying to citizens directly exposed to noise as in the case of pedestrians and bicyclists. The percentage of annoyed individuals by PTW is about 16% lower than those annoyed by the PTW and cars all together, although the PTW noise is the most relevant in terms of equivalent noise level (LAeq), (Paviotti and Vogiatzis, 2012). We remind that the equivalent noise level (LAeq) corresponds to the average received noise over the time period for which the average is taken (Gaja et al., 2003).

Noise emission and their effects are differently depending on the transport mode. The level of road transport noise results from the overlapping of the engine noise, the rolling noise and other recurring noises (Profillidis et al., 2014). Railway public transport modes such as Metro and Tramway are very important for the reduction of traffic congestion. They are considered to be sustainable means of transportation, due to the substantial reduction of air pollutant emissions by decreasing the number of cars, PTW and heavy vehicles (buses) in the urban road network. However, an important adverse effect of their operation is the increased level of ground-borne vibration and air-borne noise (Kouroussis et al., 2013; Vogiatzis, 2012; Kouroussis et al., 2014a; Kouroussis et al., 2014b).

The need for studies regarding the noise pollution and its consequences for the community has motivated various researchers on this problem in several countries. A survey in the city of Kerman reported that 70% of the participants classified the noise of their street as "very high" and 86% answered that noise produce physical and psychological annoyance to them (Mohammadi, 2009). A survey in the city of Curitiba reported that the main isolated noise sources disturbing citizens were traffic (73%) and neighbors (38%), (Zannin et al., 2003). In main roads of the city of Messina the daily average sound levels due to road traffic exceeded environmental standards by about 10dBA resulting to a 25% of the resident population

highly disturbed by road traffic noise. Environmental noise exhibits a certain degree of spatial variance resulting primarily from the peculiar geo-morphological structure of the town and from the transport infrastructure (Piccolo et al, 2003).

Walking, bicycling and public transportation are sustainable transport modes due to their environmental, societal and economic benefits (Bakogiannis et al., 2018; Botzoris et al., 2015; Botzoris et al., 2016; Galanis and Eliou, 2012; Gkavra et al., 2018). Proper infrastructure for those transport modes is necessary in order to be used from commuters for their urban trips. The implementation of audit tools for pedestrians and bicyclists urban built environment results to higher level of maintenance and change of commuters travel behavior in favor of those transport modes (Galanis and Eliou, 2012; Eliou et al., 2009; Galanis and Eliou, 2011; Galanis et al., 2014).

QUESTIONNAIRE SURVEY

Methodology and Data Collection

The survey took place in the city of Karditsa, a typical mid-sized Greek city with population of 44.002 citizens in the year 2011 (Hellenic Statistical Authority). The research was based on a questionnaire survey conducted on a random sample of 200 participants through personal interviews in the year 2016. The questionnaire was formed of 18 questions divided into two parts. In the first part (questions 1÷6), the participants stated their demographic data and personal income comparing the years 2008 (before the economic crisis in Greece) and the year 2016 (economic crisis in progress). In the second part (questions 7÷18), the participants stated the change of perceived level of traffic noise in the city of Karditsa comparing the years 2008 and 2016, the influence of traffic noise in route and transport mode choice and their willingness to increase walking and bicycling due to the reduction of traffic noise. Furthermore, they stated the perceived level of traffic noise in the street of their residence during day and night time. Moreover, they stated their awareness of traffic noise negative impacts on public health and their willingness to change their residential area for a quieter but more expensive one. Finally, they stated their awareness of the sustainable transport modes positive impacts on traffic noise reduction and their willingness to pay an additional tax in order to fund relative projects for sustainable transportation and reduction of traffic noise.

Despite the fact that the sample was random, there was an effort to select the participants as representatively as possible based on their demographic data. The answers in the survey were anonymous so the participants could answer more freely especially in the questions about their personal income. Due to personal interviews, participants were able to ask questions and receive clarifications about this survey. After the data collection was completed, followed the data analysis and export of results and conclusions.

Results

In Table 1 the results of the questions 1÷4 about the demographic data of the participants are presented. They answered questions about their age group (question 1), gender (question 2), profession (question 3) and education level (question 4). Citizens of all age groups, profession and education level participated in this survey. In Figure 1 the results of the questions 5÷6 are presented. The participants stated the level of their personal annual income (before taxes) between the years 2008 (before the economic crisis) and 2016 (economic crisis in progress). The personal income level was categorized in five groups as follows: <5,000€, 5,001€-10,000€, 10,001€-15,000€, 15,001€-20,000€, >20,000€. The results revealed an obvious reduction of citizens' personal income in the city of Karditsa during the examined years of economic crisis in Greece.

Table 1. Demographic Data of the Survey (Questions 1÷4)

Question 1: Age		Question 3: Profession		Question 4: Education	
<18	13,0%	Public servant	24,0%	Primary school	1,5%
18-25	11,0%	Private employee	17,0%	Secondary school	11,5%
26-35	16,5%	Self-occupant	21,0%	High school	32,0%
36-45	27,0%	University student	5,0%	Vocational education	12,0%
46-55	18,0%	Scholar	12,0%	TEI	14,5%
>55	14,5%	Unemployed	9,0%	University	28,5%
Sample	200	Retired	4,0%	**Question 2: Gender**	
		Farmer	6,0%	Male	57,0%
		Household	2,0%	Female	43,0%

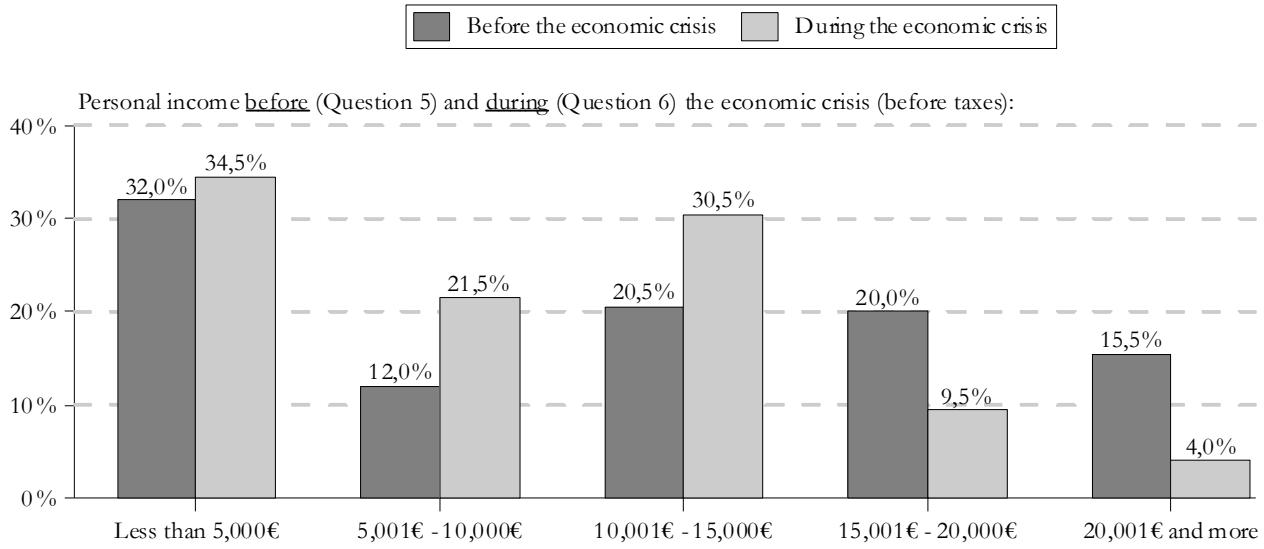

Figure 1 Personal income (before taxes) comparing the years before and during the economic crisis (questions 5 and 6).

Figure 2 illustrates the results of questions 7÷12, focused on traffic noise and travel behavior. In question 7, the participants stated the perceived change of traffic noise level in the city of Karditsa after the year 2008. The participants answered about the influence of traffic noise level in route selection (question 8), and transport mode selection (question 9). Furthermore, they answered if they prefer to walk (question 10) or bike (question 11) in case of reduced traffic noise level and they stated the most favorable actions to decrease the level of traffic noise in the city (question 12).

In Figure 3 the results of questions 13÷18 are presented, focused on traffic noise regarding the examined issues. In question 13, the participants stated the traffic noise level in the street of their residence during daytime and nighttime. In question 14, they stated if they prefer to change their residential area for a new one with lower traffic noise level but higher living cost. Furthermore, they answered if they are aware of the traffic noise negative impacts on public health (question 15) and positive impacts of sustainable transport modes in reduction of traffic noise level (question 16). In question 17, the participants stated the annual tax per capita for sustainable transportation and traffic noise reduction projects (€). Finally, they stated the level of trust to the state that successfully manage and execute relative sustainable transportation and traffic noise reduction projects (question 18).

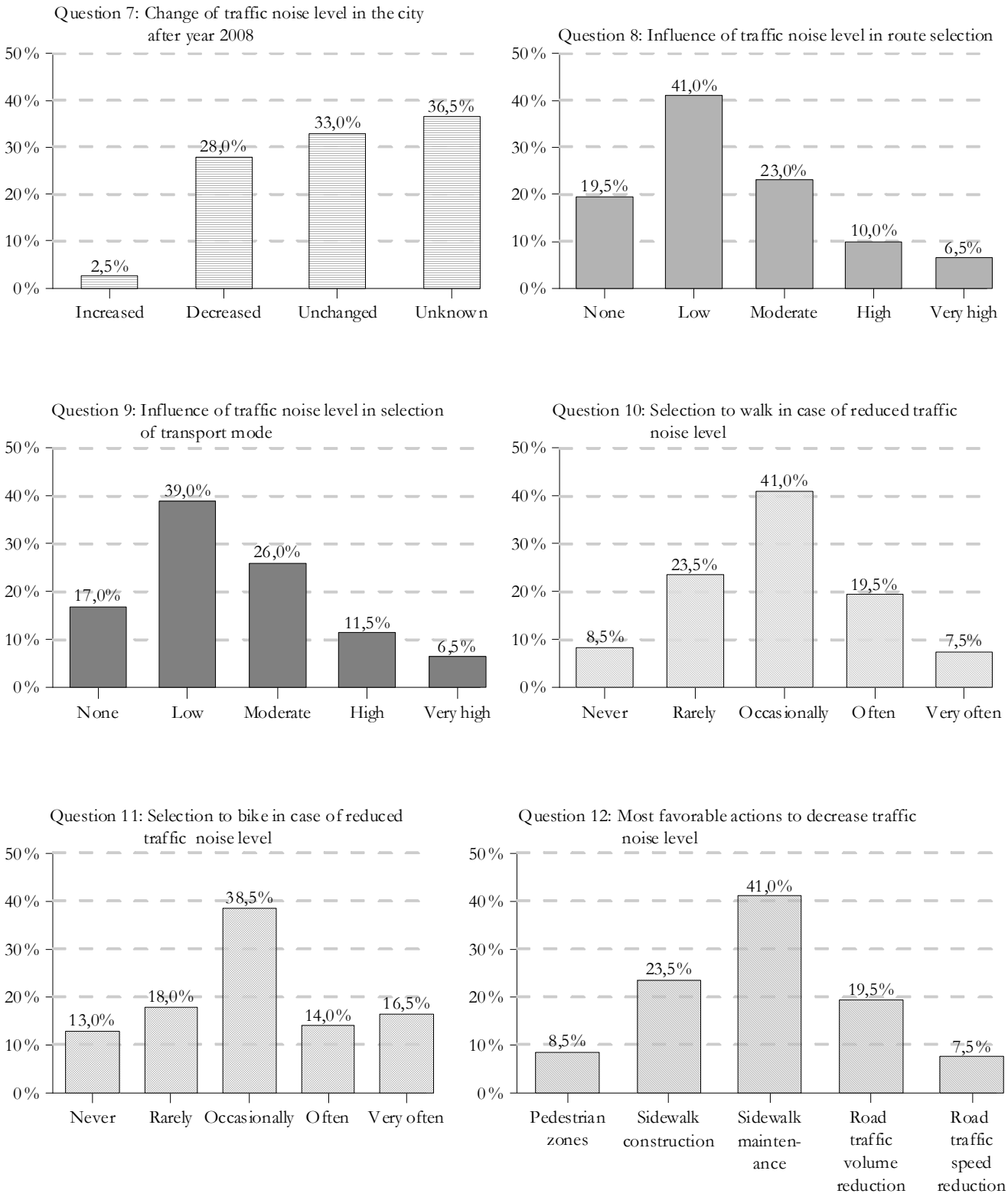

Figure 2 Change of traffic noise level after the economic crisis, influence of traffic noise in route and transport mode selection and favorable action to decrease traffic noise level (questions 7÷12).

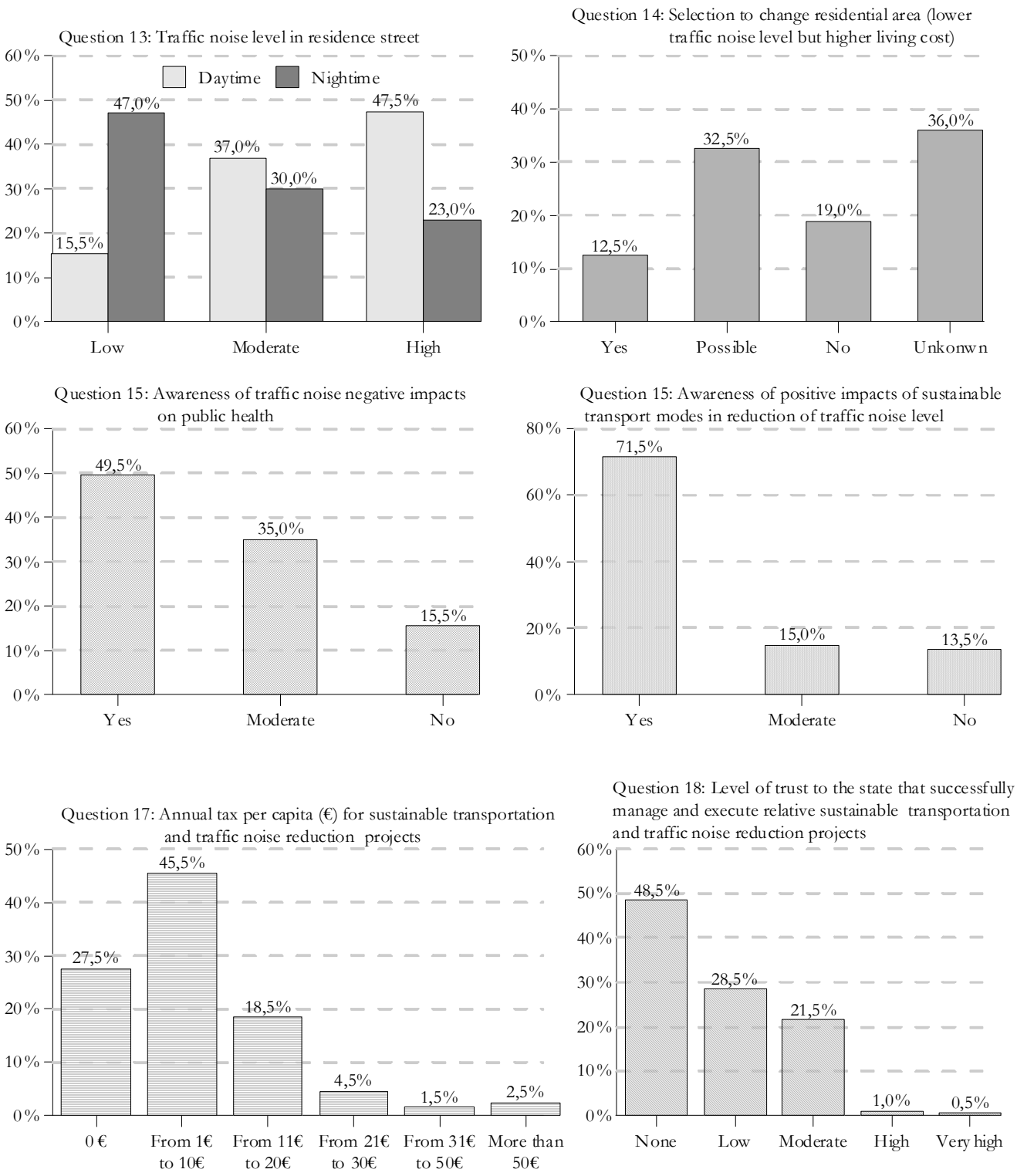

Figure 3 Traffic noise level in residential area, awareness of traffic noise negative impacts, willingness to pay for sustainable transportation and traffic noise reduction projects and level of trust to the state for sustainable transportation and traffic noise reduction projects (questions 13÷18).

CONCLUSIONS

The main conclusions of this survey are the following:

- The perceived level of traffic noise in the city of Karditsa has decreased (28.0%) or remained unchanged (33.0%) since the year 2008. It is important to mention that 36.5% of the participants could not evaluate the change of the traffic noise perceived level in their city.
- Traffic noise affects moderately commuters' selection of route (low: 41.0%, moderate: 23.0%) and transport mode (low: 39.0%, moderate: 26.0%). There is also an important part of participants who were influenced from traffic noise in selection of route (high: 10.0%, very high: 6.5%) and transport mode (high: 11.5%, very high: 6.5%).
- Participants stated that in case of reduced traffic noise level they prefer to walk (often: 19.5%, very often: 7.5%) and bike (often: 14.0%, very often: 16.5%).
- Reduction of traffic volume (68.5%) and speed (37.0%) were the most favorable actions to decrease traffic noise.
- Participants stated that the perceived level of traffic noise was high in residential street during daytime (47.5%) and nighttime (23.0%).
- Many participants stated that they prefer to change their residence area for a new one with less traffic noise but higher cost of living (yes: 12.5%, possibly: 32.5%).
- Participants were aware of traffic noise negative impacts on public health (yes: 49.5%) and positive impacts of sustainable transport modes in reduction of traffic noise (yes: 71.5%).
- Participants were willing to pay an annual tax for relative sustainable transportation and traffic noise reduction projects (72.5%), but did not trust the state to successfully manage and execute them (level of trust none: 48.5%, low: 28.5% and moderate: 21.5%).

Promotion of sustainable transportation in urban areas can reduce the traffic noise level with numerous societal, environmental and economic benefits. Citizens of Greek cities are willing to change their travel behaviour and support traffic noise reduction actions in order to reduce traffic noise and improve the quality of their life.

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Behavior of Motorcycle Riders in the Daytime and Nighttime Lighting Conditions

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ABSTRACT

Although the correlation between the lighting level and the road safety is still ambiguous numerous citations support that driving at night poses a greater risk to drivers than driving at daylight. Many contributory factors have been examined in order to identify the causes of night-time accidents e.g. conspicuity, sight, alcohol, glare from oncoming headlights, sleepiness, tiredness. Evidence suggest that single vehicle accidents involving loss of control on bends in darkness is a particular problem for young drivers who record slow rate of improvement with experience, compared with other types of vehicular accidents. The literature review infers that such accidents do not imply lack of skill but rather a risky attitude resulting in deliberate speeding. Another crucial element of the road environment apart from the bends, are the dim intersections which are more prone to accidents and hence the drivers are expected to perceive this hazard by adjusting appropriately their speed.

Aim of the present research is to investigate the behavior of motorcycle riders under different lighting conditions along rural roads where controlled and non-controlled intersections and a large number of horizontal curves are present. Field operational tests carried out within the framework of the study with the participation of young male riders of different experience level and instrumented motorcycles during daylight, dusk and nighttime. The riders travelled under free flow conditions and hence the only parameter that could potentially change their riding behavior was the artificial and natural lighting conditions. The post process of the recorded data permitted the quantitative assessment of risky attitudes and particularly the speed adjustments occurred at different times of day and night. Since a big proportion of nighttime crashes are attributed to roadway and intersection artificial lighting in many relevant researches, primarily due to the increment of driver's reaction time, the initial hypothesis of the experiments was that the participants would reduce their travel speed as the ambient illuminance decreases in order to maintain the value of the critical stopping distance constant. However, the findings showed that the riders do not substantially alter their travel speed throughout the experimental road segments either along the roadway intervals or the intersections. Therefore, the riders are not aware of the risks they are exposed to when they travel under diverse lighting conditions and hence, they are not properly trained to cope safely in travels throughout day and night.

INTRODUCTION

The literature review is full of research that make references or suggest the beneficial effect of road lighting to safety, providing evidence that the reduction in nighttime crashes is remarkable, particularly the decrease in fatal injury crashes (Frith and Jackett 2015). Since 1980 Scott concluded that a decrease of 35% in the ratio of night-to-day crashes is associated with an increase of illuminance by 1 cd/m^2 (Scott 1980). Various national guidelines determine the attributes of road lighting and the circumstances under which its installation is mandatory. However, even when the illumination levels of a road are below the standards, safety is still improved compared to the non-lit segments (Smadi, Hawkins and Aldemir-Bektas 2011). From the safety point of view the amount of road lighting has to be carefully determined since over lighting might have adverse effect to crashes ratio whilst in the environmental point of view proper lighting both in qualitative and quantitative terms will ensure energy conservation (Lucas, et al. 2013, Fotios and Gibbons 2017). Regarding the latter, it has to be mentioned that roadway lighting at Greece's municipalities is the second greater source of energy consumption after pump stations and hence any efforts to reduce the amount of energy consumed on road would be particular important (ΚΑΠΕ 2017).

In Greece the only research study relevant to the road lighting conducted by Yannis et al who processed a huge data set of police accident reports occurred between 1996 and 2008. The modes developed indicated that inadequate lighting conditions are associated with more severe accidents meaning that under dim lighting conditions not only the accidents are more but they are also more serious. The researchers concluded that traffic safety is improved with nighttime lighting which contributes to the reduction of the severity of roadway accidents (Yannis, Kondyli and Mitzalis 2013).

Within the framework of the present study four experiments took place in order to investigate the effect of ambient lighting to riders' behavior. The experiments carried out by riders with diverse riding experience along rural road segments with a great number of intersections and curves of multiple curvature with the use of four instrumented motorcycles. The motorcycles were equipped with a portable GPS device that records precisely riding performance parameters such as position and speed. The findings showed that experience is associated with the perception of the hazards due to diverse lighting conditions. However, throughout the transition hours from daylight to nighttime riders do not change their travel speed in order to mitigate the consequences of the reduced natural lighting.

LITERATURE REVIEW

Road users tend to behave in different way during nighttime and daytime either due to physical or human perceptual factors. The latter is affected by the increased consumption of alcohol and fatigue which deteriorate driver's reaction when certain potential hazards have to be dealt with. Besides during nighttime, the total time to perceive a hazard and apply the brakes is increased since the visual performance of the drivers decreases. As a consequence, although only 25% of the travel undertaken by car drivers occurs between night hours, severe night time accidents account for 40% of the total car accidents (Ward, et al. 2005). Other studies support that the number of nighttime accidents are even more, although the distance travelled at night is substantially less compared with daytime resulting in higher injury severity at nighttime accidents (Plainis, Murray and Pallikaris 2006). Therefore, travelling at night poses a greater risk of being killed or seriously injured than travelling during the day.

Rea et al (Rea, et al. 2009) reviewed 95 studies relevant to the effects of roadway lighting to the reduction of road accidents. They inferred that the absence of lighting is associated with a disproportionate large number of crashes and fatalities compared to the exposure of the drivers. The reduction varies between 4% and 40% depending on the study, the infrastructure element (freeways, intersections etc.), the crash severity, the country under investigation, the type of crash and the traffic environment (urban, rural etc.). Although the precise impact of the road lighting is ambiguous the majority of the researchers agree that the crashes during nighttime are more severe than those during daylight.

Artificial lighting as a countermeasure to road accidents

P.C. Box conducted a research regarding the before-after installation of roadway lighting along a suburb area in Chicago USA. He found a 14% overall reduction in vehicular accidents in the two-year period after the installation of the roadway lighting although the average daily traffic volume was increased by 25% during the "after" period of the study (Box 1989). Another study conducted at the same year, discussed the benefits of the roadway lighting that were recorded in a previous study which concluded that a 30% reduction of nighttime casualties due to road accidents is expected. The benefits of the roadway lighting were justified by the augmented visual performance when the light levels are increased. The research also provided a figure depicting the correlation between the risk and the amount of the light level. It is worth noting that according to this figure the risk reaches a point after which it is not reduced with the increase of the light level. That implies that there is a certain amount of light where the maximum safety benefits and the minimum energy consumption are met (Schreuder 1989).

The link between the street lighting and the road safety is the subject of many other researches, the majority of which indicate certain percentages of fewer accidents due to the installation or improvement of roadway or intersection lighting. Two of the oldest ones document a reduction of 30% in road accidents along urban roads with improved lighting conditions as mentioned in a later study (Willis, Powe and Garrod 2003). A study investigating the nighttime accidents cites five researches supporting the opinion that the driver's ability to properly react in order to avoid a collision worsens under dim lighting conditions (Plainis, Murray and Pallikaris 2006). In a more recent study in New

Zealand a reduction in crashes of 30% is mentioned both nationally and worldwide in several "before-after" studies when lighting was improved. The benefits from road lighting is also indicated clearly in this study which includes an analysis of the accidents during nighttime and daylight and concludes that the night/day crash ratio versus the average luminance follows a linear relationship (Jackett and Frith 2013).

Rajaram Bhagavathula (R. Bhagavathula 2015) in his dissertation thesis studied how an intersection lighting design results in the optimum nighttime visibility striving to determine the effect of illuminance on visual performance at intersections and finally understand how object luminance, contrast, and visibility interact with each other. In his comprehensive literature review he cites a great number of studies relevant to intersection lighting which document night-to-day crash ratios and rates reductions ranging from 13% to 45% respectively. The greatest reduction is recorded to nighttime fatal accidents with a reduction of 65% after the installation of lighting on both intersections and road segments. The analysis performed by Bhagavathula to the data collected from 100 rural intersections showed that the night crashes are reduced by 7% for 1 lux increase in illuminance level whilst another study increases this percentage to 9% (C. Edwards 2015). When the subject of the analysis is solely the lighted intersections Bhagavathula et al concluded that the reduction to nighttime accidents for 1 lux increase is 99%. Additionally, in their report they cite 13 research studies which also support that lighting is beneficial in terms of safety whilst they also provide references that an average illuminance of 20 - 30 lux or more is associated with less crashes (Bhagavathula, Gibbons, et al. 2017). Nevertheless, in none of the studies an upper threshold to the illuminance level is mentioned implying unlimited reduction in crash rates as the lighting increases.

Many local authorities for environmental and economic reasons decided to reduce or turn off road lighting in an effort to reduce the energy consumption. The results of this policy are included in a report that was published in New Zealand and indicate an increase in nighttime crashes ranging from 13%-30% (Frith and Jackett 2015). The benefits of road lighting are documented in another study which suggests that the modification of an intersection from unlit to lit is followed by a reduction of 94% to nighttime crashes (C. Edwards 2015). As mentioned in the same study, Isebrands et al also concluded that at lit intersections 36% less crashes occur. Similar references are also included in a study published in the Journal Lighting Research and Technology indicating reductions in road accidents depending on the origin of the research and the element of the infrastructure (intersection, freeway etc.) after installing or upgrading road lighting (Fotios and Gibbons 2017).

Artificial lighting as a cost-effective measure to road accidents

The design, installation and maintenance of roadway lighting require certain resources and hence the profit from the reduction of accidents, which is rather well documented according to the previous chapter, has to be compared with the cost of lighting. In this direction Minnesota Department of Transportation carried out a research project in order to identify whether lighting can be used as a countermeasure to moderate the consequences and frequency of nighttime accidents. The findings published in 1999 confirmed that the use of lighting at rural intersections is twofold. Not only it reduces nighttime crashes but is can also be considered as a cost-effective countermeasure (Preston and Schoenecker 1999). These findings were evaluated and verified again in 2006 (Isebrands, et al. 2006).

Another study aiming at proposing safety improvements by investigating the lighting levels at isolated intersections, cites a report which performed a cost benefit analysis and concluded that the economical ratio when weighing the benefits from property damage, injuries and fatal accidents with the costs of maintaining and operating road lighting is beneficial by 15:1 (C. Edwards 2015). The cost effectiveness of lighting is also mentioned in a study from Washington State which mentions that FHWA consider the illumination as the most significant countermeasure against road accidents due to the fact that the safety benefit to cost ratio was the highest compared to other devices (Schalkwyk, et al. 2016).

Nevertheless, as mentioned in a study which combined the findings of two major projects in order to investigate the impact of lighting on interchanges, the continuous road illumination might not be considered as a productive measure to reduce crashes. The researchers recommended that further investigation is necessary to shed more light on the cost-benefit burden in terms of lighting policy (Venkataraman, et al. 2011). The finding of another study also concludes that the continuous illumination on freeways cannot be associated with improved safety performance

(Schalkwyk, et al. 2016).

Limitations of artificial lighting

Although the benefits from installing and maintaining road lighting have been amply documented, many researchers do not recommend the propagation of lighting poles to the road network expressing environmental and safety concerns. The main point of discussion has to do with the amount and not just the presence of lighting that is necessary in order to ensure the safest driving environment without wasting energy and hence the knowledge of the lighting attributes is the key element to accomplish this target (C. Edwards 2015). The glare caused by the headlights of oncoming vehicles is mentioned as an inevitable problem by Ward et al (Ward, et al. 2005) who also inferred that the exact reduction of road accidents due to the better adjustment of the lights is still not clear. Glare is also mentioned in another study as a safety and environmental problem to over-lighting intersections due to the reduction of visibility that cause to the drivers and energy wastage respectively (R. Bhagavathula 2015). Therefore the establishment of the illuminance in such level that provides the best road environment in terms of visual performance without causing glare or discomfort to the road users is of paramount importance (Bhagavathula, Gibbons, et al. 2017).

Moreover, many researches are skeptical regarding the effect of illumination in reducing road accidents. A study conducted by Willis et al (Willis, Powe and Garrod 2003) could not identify the extent of which the lighting improvement lead to accident reduction confirming that the link between lighting and injuries is vague. Few years later Crabb and Crinson expressed the opinion that the studies showing reduction in nighttime accidents are only applicable to limited circumstances for instance to certain types of roads or specific speed limits. They also mentioned that due to the fact that lighting provides a safer road environment to the drivers they might increase their travel speed and reduce their concentration and hence compensate any benefits gained with the installation or improvement of lighting (Crabb and Crinson 2009). That is also in accordance with the findings of Yau et al who concluded few years earlier that severe vehicle accidents are associated with good lighting conditions probably because during night the drivers are more alerted and reduce their travel speeds (Yau, Lo and Fung 2006). Another study also mentions that in certain road segments the accident ratio is lower in the unlit compared to lit locations (Frith and Jackett 2015). The latter research also suggests that the uniformity and not the illuminance level is the most important variable in road safety. Schalkwyk et al concluded that at some road sections lighting may have the opposite effect of what is initially expected and makes reference to a number of points of concern due to the operation of road lighting such as the carbon footprint, the impacts on plant, the impact on animal and human life and the contribution to light pollution (Schalkwyk, et al. 2016). Besides, the same study cites a research conducted by Venkataraman et al who suggest that lighting can have either positive or negative impact to road safety depending on the road segments under investigation.

Perkins et al studied the impact of street lighting on crime and traffic injuries at night in order to determine whether the reduced street lighting policy that was adopted recently by the authorities of England and Wales aiming at the decrease of carbon emissions and energy cost, is effective or not but failed to find a strong correlation between reduced street lighting and road traffic injuries (Perkins, et al. 2015). Smadi et al carried out a research program at rural unsignalized intersections and inferred that the quantification of the effect of lighting at intersections is rather difficult and has not been accomplished yet (Smadi, Hawkins and Aldemir-Bektas 2011). Similar opinion was expressed by Edwards who also stated that the exact amount of light that is necessary to improve safety at rural intersections has not been determined yet (C. Edwards 2015). Besides Seva et al who conducted a study aiming at investigating motorcycle accidents in the Philippines, concluded that the lighting conditions were not found to be a significant predicting variable for motorcycle accidents and suggested to increase traffic rider's conspicuity in junctions as a more effective measure (Seva, et al. 2013).

Failure to come up with a statistical significant correlation between the crash rates and the road lighting is cited in a recently published study by Gibbons et al who also concluded that the degree of which the driving behavior is improved under enhanced road lighting conditions is greater for drivers of 50 years old and over compared to the younger ones (Gibbons, et al. 2015). The visual performance of a human eye is time dependent meaning that a driver suffers loss of contrast and reduced visual acuity as he is getting older which is augmented with time. Therefore, these phenomena should be taken under consideration in any relevant research, especially in Greece where population is

ageing rapidly (Jackett and Frith 2013, R. Bhagavathula 2015, Frith and Jackett 2015). That finding could justify a reference made by Frith and Jackett, that indicates an upper threshold of 16 lux above which safety begins to decrease with increased lux (Frith and Jackett 2015).

Lastly, another aspect of nighttime driving performance has to do with the attitude of the drivers who are more likely to consume alcohol and be affected by fatigue. These variables might bias any research concerning the effect of lighting to road accidents (Fotios and Gibbons 2017).

Literature review conclusions

The majority of the researchers agree that a lighted roadway or intersection provide safer road segments to the passing vehicles. However quantitative and qualitative aspects are still under investigation regarding the optimum amount, uniformity, horizontal and vertical lighting in order to maximize the safety benefits by reducing nighttime crashes and minimize the energy consumption (C. Edwards 2015). As discussed in a recently published report from Washington, the meta-analysis of 37 studies revealed that in 81% of the cases lighting indeed improved safety while in the rest 19% safety was deteriorated (Schalkwyk, et al. 2016). Besides according to the literature review the root cause of the vehicular accidents is usually the erroneous driver's action and not his failure to perceive the hazards. Therefore, the cognitive instead of the perceptive aspects are more important during the driving task (Schreuder 1989). That is also confirmed by Clark et al who suggest that the failure of attitude results in deliberating speeding (Clarke, Ward and Truman 2002). It is worth noting that speeding is included among the main causes of road accidents, particularly along unlit country lanes (Ward, et al. 2005). On the other hand a study conducted by Plainis et al supports that a great number of road accidents are attributed to human perceptual errors and their contribution should be investigated together with engineering factors and particularly with the road environment and the maintenance of the vehicles (Hills 1980).

Since the reaction of human beings to visual stimuli differs based on the context, the findings among the researchers are quite contrasting and hence further investigation on the effects of lighting to the road users is recommended (Seva, et al. 2013). However, it is apparent among the researchers that the increase in illuminance levels enhances the visual performance by increasing both the speed and accuracy of the information that can be extracted from the environment and hence the various objects that constitute the road environment can be detected more easily (R. Bhagavathula 2015). The importance of the reaction time in visual performance and as a consequence to road safety is also referenced by Fotios and Gibbons. However they cite two research studies which support that although the impact of lighting to visual performance is beneficial at low light levels, after a certain point of luminance the visual performance does not improve and hence further increase in illuminance level does not lead to nighttime crash reductions (Fotios and Gibbons 2017). Therefore, the overarching goal of the research has to be the determination of the threshold illuminance level above which no other safety benefits are gained. This goal is crucial not only for safety but also for environmental reasons.

DATA COLLECTION AND ANALYSIS

Aiming at the investigation of the correlation between natural lighting and riding behavior, field operational tests carried out along four rural road segments with the participation of five riders and the use of a GPS data logger under diverse lighting conditions. More specifically, three different time periods were set for the execution of the experiment. The first one was set between 12:00 and 16:00 (daylight), the second one between 22:00 and 01:00 (nighttime) and the third one between 18:00 and 20:00 (dusk). Apparently, apart from the lighting conditions all the other environmental and weather conditions were equivalent for all three time periods. Along the first three road segments the riders traveled during daytime and nighttime while along the fourth one the riders traveled during daytime and dusk. The participants rode from the start of each road segments to the end of it and vice versa under different lighting conditions producing 24 measurements at the four experimental routes for statistical process. The set up of the experiments is described in detail at the following subchapters.

Initial Hypothesis

Since the critical stopping distance is dependent on the ambient lighting conditions the riders would have to change their travel speed during nighttime compared to daytime in order to maintain the same possibility to get involved in hazardous situations. Having as granted that the reaction time is increased during night (Plainis, Murray and Pallikaris 2006), the travel speeds are expected to be lesser during the nighttime travel. Indeed, driving at night along bends located at non- built up areas is a particular problem especially for younger drivers who fail to retain the control of their vehicle (Ward, et al. 2005).

Green et al also inferred that during nighttime single vehicle crashes occur more frequently at rural curves (Green, et al. 2003). Overhead artificial lighting along the road segments where the measurements tool place is absent and hence the only lighting ahead of the drivers was coming solely from the vehicle's low/high beam headlamps. As stated in a recent study (R. Bhagavathula 2015), in such conditions the detection distance might tripled whilst riders might not be able to stop inside the illuminated area ahead if they travel over 40 km/h. Moreover, along non-lit road segments the drivers are more likely to overdrive and as a consequence they fail to identify objects on the pavement or critical information of the road environment (e.g. signage) on time (C. Edwards 2015). Therefore, the riders', especially the experienced ones, are expected to reduce their travel speeds along the road segments where the experiments took place during nighttime and dusk.

Design of the Experiment

Single vehicle accidents are the key crash type of road accidents along rural roads as discussed in a relevant study (Frith and Jackett 2015, 32). The primary objective of the experiments was to obtain a data set of speed profile recordings, for various motorcycle riders, along the bends and the intersections of the road segments where the measurements took place, especially under different lighting conditions due to the fact that adjacent to these two elements of the infrastructure road accidents are overrepresented compared to the remaining of the road (SWOV 1994).

The equipment that was used was based on GPS technology together with a data logger. Video Vbox of Racelogic combines a GPS data logger with a solid-state video recorder and records a set of riding behavior parameters such as position, speed and acceleration very precisely. Particularly speed is recorded with an accuracy of ± 0.20 Km/h rendering Video Vbox as ideal for the execution of the experiments.

The instrumented bikes that were used to carry out the field measurements was a BMW F650, a Honda SH 50, a Honda Innova 125 and a Honda CBF 250 all of them particularly widespread on rural Greek roads.

Experience is a significant factor that determines the level of risk taking behavior among riders. In order to reduce the probability of accident occurrence during the experiment, young and older riders were excluded, due to their high risk rates. Consequently, all participants had to have an actual riding experience of at least 5 years and should not be older than 50 years old. Aiming also at the latter target, the sample of riders was biased towards riders with limited accident records. Furthermore, since one of the main objectives of the present research was to determine how the riding experience affects riding behavior, efforts were made in order to match the overall participants' features apart from their riding experience, which was selected to be considerably different.

Taking under consideration the afore-mentioned, two male riders belonging at the same age group were selected to carry out the field measurements of the first three road segments and three riders to execute the experiment of the fourth one. None of them revealed any obvious reason of impaired riding ability while their riding experience levels were totally different. Moreover, they had common stay of residence, adjacent to the routes where the experiment was conducted and therefore, they both had similar familiarity with the experimental environment. Prior to the execution of the field measurements, they were asked to ride the instrumented motorcycles until they felt confident with its operation and to fill out a designated for the purposes of the experiment's questionnaire.

Experimental environment

In order to limit the variability and complexity of the riders' behavior, efforts were made so as to maintain similar conditions during each experiment. For this reason, factors such as weather conditions, temperature, presence of other users on the road during the measurements, condition of the motorcycle etc., were alike throughout the execution of

the field measurements and hence, the comparability of the data obtained from the recording equipment was ensured. The selection of the experimental environments had to be based upon four primary conditions: the location, the type of the road, the weather conditions and finally, the time and date that the experiments would be conducted. All of these four conditions had to be common for all riders in order to record comparable data. In addition, the location of the experiments should ensure on the one hand the constant function of the recording device, and on the other hand null traffic volumes throughout the experiments in order to achieve unaffected riding behavior. Finally, for purely practical purposes, the experimental environments sought close to the individuals' place of residence.

Taking into account the requirements mentioned above, the road network that would serve the needs of the research and meet the requirements of the experiments was mountain Pelion, in Magnesia. In a more detailed investigation, the following road sections were determined as appropriate to carry out the field measurements:

- 1rd road section: Part of rural road Afyssos – Afetai (39°16'30.24"B, 23°10'1.12"A to 39°16'53.69"B, 23°10'41.10"A). Length: approximately 2.300 m
- 2st road section: Part of rural road Milina – Lafkos (39°10'6.58"B, 23°13'43.97"A to 39°10'0.43"B, 23°14'21.94"A). Length: approximately 2.300 m
- 3nd road section: Part of rural road Neohori – Kalamaki (39°18'43.98"B, 23°12'49.28"A to 39°19'23.41"B 23°11'45.51"A). Length: approximately 2.550 m
- 4th road section: Part of rural road Argalasti – Syki (39°16'34.10"B, 23°12'26.52"A to 39°17'03.21"B 23°15'21.72"A). Length: approximately 5.000 m.

It has to be noted that, the orientation of the fourth road segment is West – East and hence, during dusk throughout the travel from Argalasti – Syki the sun was behind riders while from Syki – Argalsti the sun was ahead of them. In none of these road segments overhead lighted was present during the execution of the experiments. Regarding the weather conditions and in order to restrict the parameters that affect the riding behavior of the participants, all riders were instructed to cease the measurements when the pavement was even slightly wet or during cloudy or foggy days in order to maintain constant natural lighting. In general, the instructions that were given to the riders, forbidden the execution of the experiment in case any environmental or traffic conditions might divert their regular riding behavior. It is also noted that the unimpeded travel by other drivers achieved by ensuring null traffic volumes. For that purpose the measurements were conducted when the road was free from the presence of other road users.

Data processing method

The data analysis was based on three program packages; Vbox Tools v2.2.2 b042 of Racelogic (http://www.racelogic.co.uk/), Excel 2007 of Microsoft (http://www.microsoft.com) and Autocad 2009 of Autodesk (http://www.autodesk.com). The raw data files recorded at the SD card (extension *.vbo) were opened using Vbox Tools and converted to comma delimited files (extension *.csv). Each *.csv file corresponded to a specific measurement and contained 3 columns; velocity, coordinate x and coordinate y. Note that these values were recorded at a sampling rate of 10 Hz.

All of them were then numerical labeled in ascending order starting from 1 for the first point of each measurement in order to facilitate the design of the trajectories to AutoCAD. The final outcome of this process was the production of the speed profile and the trajectory of each repetition along the experimental road segments.

Results

After the completion of the measurements and the post process of the raw data as described in Chapter Data processing method, the mean speeds of the riders at the four road segments were calculated as shown in **Table 1**.

Table 1. Mean speeds (km/h) per lighting condition and route

Condition	Afysos - Afetes	Milina - Lafkos	Neohori - Kalamaki
Inexperienced Daylight	39.27	51.26	67.19
Experienced Daylight	39.50	50.05	65.08
Both riders Daylight	**39.40**	**50.66**	**66.14**
Inexperienced Nighttime	40.59	44.23	58.15

Experienced Nighttime	36.06	47.80	58.35
Both riders Nighttime	**38.33**	**46.02**	**58.25**
	Syki - Argalasti	**Argalasti - Syki**	
Inexperienced Daylight	69.41	73.28	
Experienced Daylight	59.57	64.81	
Both riders Daylight	**64.49**	**69.05**	
Inexperienced Dusk	69.96	72.97	
Experienced Dusk	63.18	64.08	
Both riders Dusk	**66.57**	**68.53**	

The riders travel faster during dusk when the sun is behind their back (Argalasti – Syki measurements) due to the fact that under such conditions glare is absent. That finding is applicable for both inexperienced (4.1% increase) and experienced (1.4% increase) riders. According to the measurements the riders do not change significantly their travel speeds during dusk compared to daylight and hence they do not perceive the decrease of ambient lighting as a threat.

However, the experienced participant reduces his speed profile during nighttime compared to daylight (ranging from 4.7% το 11.5%) probably because he compensates the absence of natural lighting with the reduction of the travel speed. Nevertheless, the inexperienced rider throughout the first route increases his travel speed during nighttime while at the second and third route he follows the behavior of the experienced rider by reducing his travel speed by 15.9% and 15.4% respectively. Therefore, there are indications that experience is associated with the consequences of the absence of overhead lighting and hence novice riders should be trained properly to drive safely under diverse lighting conditions.

The results also show that experience is not correlated with travel speed. Indeed, along all four routes the experienced riders do not travel faster than the inexperienced ones nor vice versa. Particularly, at the fourth route the inexperienced rider travel faster than the experienced riders. This finding can be attributed to the risky attitude of the inexperienced rider based on the questionnaire that all participants filled in prior to the execution of the experiments. Consequently, no conclusions can be drawn regarding the link between experience and speed.

In a more detailed analysis of the raw data it was revealed that all riders travel faster along left-handed horizontal curves which radius is less than 100 m independently of the lighting conditions. No explanation could be inferred in order to justify this finding and hence further research on this matter is recommended.

CONCLUSIONS

According to the literature review that was preceded, driving at night is more dangerous compared to daytime and artificial lighting is an effective counter measure in order to prevent nighttime accidents. However, the attributes of the lighting that minimize the vehicular accidents together with the energy consumption is still under investigation. Until the optimum lighting conditions are precisely determined the road users must be properly trained in order to be aware of how their ability to respond to an emergency is affected under dim lighting conditions (Plainis, Murray and Pallikaris 2006) and how they must alter their driving behavior in order to retain the same risk as with daytime. Even in that case, the occurrence of an accident is usually the result of more than one factors interacting to each other and hence the precise effect of lighting individually is rather impossible. Besides the way the various variables effect the accident rates has not been defined precisely yet (Crabb and Crinson 2009, Bhagavathula, Gibbons, et al. 2017).

Based on the results of the measurements the following conclusions can be drawn:

- Riders reduce their travel speed when their vision is towards the sun. That finding is applicable for both experienced and inexperienced riders.
- Lighting conditions during dusk do not cause speed reduction, irrelevant to the level of experience meaning that although the reaction time and consequently the critical stopping distance in order to safety negotiate an urgent hazard is longer during dusk the riders fail to perceive this risk and keep their travel speed constant.
- The experience rider reduces his travel speed during nighttime compared to daylight. However, the inexperience rider does not constantly follow this behavior along all routes implying lack of awareness.
- The amount of speed is not associated with experience regardless of lighting conditions. Since

inexperienced riders travel at similar speeds with experienced ones a matter of safety emerges.

- There are indications that the direction of the horizontal curve (right/left-handed) affects travel speed.

RECOMMENDATIONS FOR FUTURE RESEARCH

Since the degree at which each variable contributes to an accident is not clear yet, the determination of the lighting conditions that provide the safest possible road environment is rather impracticable. Instead the focus of the research on the links between driver's perception of safety and actual level of safety is highly recommended. The ultimate target will be the determination of the optimum driving behavior on the basis of precisely defined quantitative and qualitative attributes in order to retain an acceptable level of risk under any conditions. The final outcome will be twofold: on the one hand the maximum safety level will be achieved while on the other hand the waste of energy will be minimized.

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