How much do Greek drivers know about safety when driving through road tunnels?

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Safety on the transportation domain is a matter of great importance for each country's authorities. Drivers' behavior on the road is the main cause or an aggravating factor in one out of three road accidents. Tunnels, as a crucial part of road infrastructure must be at the center of attention in regard to drivers' behavior. Greece, is among the European member states with the highest number of Trans-European Road Network tunnels. However, previous research endeavors have indicated that Greek drivers have significant deficiencies in adopting appropriate behavior while driving through tunnels. This study presents the results of an online questionnaire survey conducted to explore tunnel drivers' knowledge and driving habits in Greece. A sample of 1,274 responses was collected and analyzed. Drivers' level of knowledge regarding the tunnel safety has been examined, investigating knowledge regarding, for instance, the existence and proper use of tunnel equipment or knowledge regarding appropriate driving behavior in case of emergency. Driving habits have also been investigated, with special emphasis on understanding the perception of drivers when comparing themselves to other drivers. Findings suggest that the familiarity of the respondents with tunnels is increasing, however, there are still significant knowledge and behavioral gaps. To sum up, this study provides important information that can be deployed by both the authorities in developing better educational strategies and tunnel operators in designing relevant information campaigns.

Keywords: Tunnels, Greece, Questionnaire survey, Road infrastructure, Safety, Drivers' behavior.

1. Introduction

1.1 *Setting the scene*

Safety on the transportation domain is a matter of great importance for each country's authorities since it has a major impact on both the economic growth and the quality of life. Despite the significant advances regarding road safety in recent years, road accidents continue to be the cause for a considerable high number of deaths and injuries. Recent studies have shown that road crashes result in approximately 1.24 million deaths per year globally while injuries are more than 1.2 million (WHO, 2015). In order to ensure a high level of safety, drivers' behavior should be primarily examined. Official reports indicate that drivers' behavior on the road is the main cause or an aggravating factor in one out of three road accidents (EC, 2018). In particular, the influence of infrastructure on

Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference
Edited by Piero Baraldi, Francesco Di Maio and Enrico Zio
Published by Research Publishing, Singapore.
ISBN: 978-981-14-8593-0; doi:10.3850/978-981-14-8593-0

driver behavior cannot be ignored due to its impact on a significant number of accidents (Kareklas, 2016). Meanwhile, because tunnels are a crucial part of the road infrastructure, they must be at the center of attention in regard to drivers' behaviour (PIARC, 2016). Therefore, there is a need to continuously improve the safety level of such infrastructure (Kirytopoulos & Kazaras, 2011).

Road tunnels are important infrastructure elements since their use improves transportation flow within urban areas, enables crossing mountainous areas while it minimizes the environmental impact, the time and the transportation costs. Besides, the rapid improvement of underground technology has rendered tunnels as a cost-effective engineering solution in developing new road networks. As a consequence, their number is increasing worldwide (Ntzeremes & Kirytopoulos, 2019).

Although tunnels do not exhibit necessarily higher accident rates in relation to the rest of the road network (Bassan, 2016), if an accident occurs in a tunnel, it can cause more severe consequences than if the accident occurs at an open section of a road. The severity of tunnel accidents is related to some special attributes of this kind of infrastructure (Ntzeremes & Kirytopoulos, 2018). Due to the lack of physical light, tunnels are considered as a hostile driving environment. Therefore, drivers meet with difficulties to adjust when passing through tunnels (Domenichini, et al., 2017). This is related to the changing lightning conditions, which cause the black hole effect at the entry portal and the glaring effect at the exit portal. Additionally, tunnel attributes as a confined space have a crucial role regarding fire accidents, which form the most serious threat for tunnel systems. Fires in tunnels characterized by combustion irregularity, which develops higher heat release rates along with large amount of toxic smoke (Li & Ingason, 2018). These features combined with the difficulties in approaching and rescuing trapped-users justify their increased severity.

The role of drivers is significant in order to achieve a high level of tunnel safety (Mühlberger et al., 2008). Studies have indicated that the majority of tunnel accidents are caused by rear-end collisions, poor maintenance of vehicles and disobedience of drivers in keeping a safe distance from vehicles in front. Regarding tunnel fire accidents, the most common causes are the collisions between vehicles or between vehicles and the tunnel structure followed by faults of mechanical or electrical nature e.g. overheated bearings or brakes, etc. (Nævestad & Meyer, 2014). Furthermore, it has also been indicated that the terminal zones of tunnels and also approach zones to tunnels are more prone to accidents than the central zones (Bassan, 2016).

1.2 *Objectives*

Although deadly road accidents in European tunnels seem to become less among the years between 2010 and 2019, they still attract the public concern (Ntzeremes & Kirytopoulos, 2019).

Greece, is among European Union (EU) member states with the highest number of Trans-European Road Network tunnels. However, previous research endeavors indicated that Greek drivers have significant deficiencies in adopting appropriate behavior while driving through tunnels (Kirytopoulos et al. 2017; Zeeri et al. 2019).

To this respect, this study presents the results of an online questionnaire survey conducted to explore current tunnel drivers' knowledge and driving habits in Greece. A sample of 1,274 responses was collected and analyzed. Drivers' level of knowledge regarding the tunnel safety has been examined, investigating knowledge regarding, for instance, the existence and proper use of tunnel equipment or knowledge regarding appropriate driving behavior in case of emergency. Driving habits have also been investigated, with special emphasis on understanding the perception of drivers when comparing themselves to other drivers.

By investigating drivers' knowledge about tunnel safety, as well as their habits when driving through tunnels, this study provides important information that can be deployed by both the authorities in developing better educational strategies and tunnel operators in designing relevant information and awareness campaigns.

1.3 *Previous works*

Despite the large number of tunnels existing in Greece, only a few studies have been conducted regarding the safety issue and the role of drivers within it. Road safety statistics indicate that Greece, during the years 2010-2017, despite the significant reduction in fatalities occurred by approximately 41%, compared with the 20% reduction average for the EU, still has one of the highest number of deaths with 76 deaths per million inhabitants while the European average is 50 (EC, 2018). Considering the more severe consequences of a traffic accident in tunnel, the outcome above should drive and motivate those responsible for tunnel safety to initiate relevant actions.

Besides, the studies already carried out illustrate some serious deficiencies regarding both knowledge and behavioral intentions of Greek drivers, when passing through tunnels.

Initially, Kirytopoulos et al. (2017) study through which 1,129 drivers participated in an on-line questionnaire survey, aimed to explore road tunnel users' awareness and to identify potential knowledge gaps. The results showcased that despite the adequate driving experience of the participants, since 44% of them had more than thirteen years of experience, there was a significant part of survey participants who exhibit serious knowledge gaps regarding the recommended behaviors in both normal and safety critical situations. For instance, a large proportion of survey participants did not realise that driving in tunnels requires different safety approach than driving in the open road. 54.4% of the respondents stated that they consider no difference when driving via a tunnel than on the open road. This attitude raises the lack of safety awareness by the drivers, something that should have been pinpointed through both information campaigns and driving lessons. Furthermore, the results indicated the absence of information campaigns in Greece since a significant part of the respondents declared that they did not receive any kind of such information. Unfortunately, only the 22.1% of the respondents stated that they have received information on this issue. Serious knowledge gaps have been identified such as for example regarding the compliance of the drivers in keeping appropriate distances from the cars in from of them. Although the enclosed nature of road tunnels that require stricter measures for preventing accidents, the majority of the respondents stated that they did not keep the appropriate distances. Another gap was pinpointed regarding the drivers' behavioral intentions in case of a fire accident. It was shown that people were prone to make U-turns, to drive in reverse gear and try to overtake burning vehicles.

Additionally, Zeeri et al. (2019) survey explored road tunnel drivers' behavioral intentions in Greece. To do so, a questionnaire survey was conducted through which 306 responses were collected and analyzed. By comparing respondents' behaviors with the behavior of other drivers around them, it was found that while participants believed that they adopted safer driving behavior than other users, and while they believed that they drove more carefully inside road tunnels than they did on the open road, almost none adhered to speed limits, nor maintained the appropriate safety distance. The respondents believed that inside road tunnels they had better driving control, an accident was more possible to occur and the consequences of such an accident would be more severe than on an open road section. At last, it seemed that Greek drivers were not familiar with the use of fire extinguishers and emergency telephone booths, nor willing to leave their vehicle at the case of an accident. Finally, they displayed a strong trust in authorities.

2. Method

2.1 *Recruitment of respondents*

In order to collect the data needed to conclude about both the knowledge regarding tunnel safety and the driving behavior of Greek drivers, a questionnaire was conducted and administered online. Respondents were recruited through web posts in sites relevant to driving, cars and road safety. The final sample consisted of 1,274 responses that were analysed and are presented in this paper.

2.2 *Structure of the questionnaire*

Including the socio-demographic questions, the part of the questionnaire presented in this paper consisted of 26 questions, which were allocated in two sections; the one focused on analyzing drivers' knowledge on safety issues and the other which focused on analyzing driving habits. Regarding questions' type, some of them were formed as stated preference multiple choice questions while others were formed as typical Likert-style questions. In detail:

- Seven (7) questions concerned socio-demographic variables:
  - (i) The Age
  - (ii) The Gender
  - (iii) The Years of active driving
  - (iv) The driver's profile, i.e. professional driver.
  - (v) The level of education
  - (vi) The driving frequency through tunnels
  - (vii) The information received regarding tunnel safety issues
- Nine (9) stated preference multiple choice questions concerning drivers' knowledge on tunnel safety issues, where respondents can choose either only one answer or more than one:
  - (i) Driver's knowledge on behaviour during normal driving conditions.
  - (ii) Driver's knowledge regarding tunnel's safety equipment.

(iii) Driver's knowledge about tunnel signalling with emphasis in emergency facilities informative signs.
(iv) Driver's knowledge regarding available communication channels in case of emergency.
(v) Driver's knowledge on whether passing or not through the fire location in order to drive out of the tunnel.
(vi) Driver's knowledge regarding U turns.
(vii) Driver's knowledge regarding the use of emergency telephones.
(viii) Driver's knowledge regarding the use of telephone booths.
(ix) Driver's knowledge on when it is allowed to stop inside a tunnel.

- Five pairs of questions (in total 10 questions) concerning the driving habits of the tunnel users, as well as their opinions on others' driving habits inside road tunnels. These questions were about the:

(i) Level of compliance with turning on the lights; answers on a six-point Likert scale from never to almost-always.
(ii) Level of avoiding lane hopping inside tunnels; answers on a six-point Likert scale from never to almost-always.
(iii) Level of compliance with the speed limits; answers on a six-point Likert scale from never to almost-always.
(iv) Level of maintaining safe distances in case of emergency.
(v) Level of maintaining safe distances when driving through tunnels.

All the 1,274 responses were valid. The sample data for each variable of the questionnaire was examined by the Kolmogorov-Smirnov test for identifying whether the variables distributions deviated significantly from the normal distribution. The tests concluded that the data from all the variables (questions) was not normally distributed. This dictated the use of non-parametric tests for the subsequent analysis thus, the Wilcoxon test was used in order to test differences between the mean values of two variables (e.g. mean for variable X against mean for variable Y), and the Mann–Whitney test was used to test the differences of means between two sub-groups for the same variable (e.g. difference of mean for variable X for men and women). The Kruskal-Wallis test was employed to examine the differences in the mean value among several independent groups for a specific variable (Field, 2009).

3. Results and Discussion

3.1 Participants' profile

Of the 1,274 valid responses, 1,095 (85.9%) are male respondents and the remaining 179 (14.1%) are female. Regarding the age distribution (Fig. 1), the majority, *79.4%*, is aged between 26 and 55 years old, while most of the research participants, *33.7%*, belong to the age group 36-45.

The mean years of active driving are *22.53*, and *56%* of the respondents state that they use road tunnels "from sometimes a month" to "sometimes a day". Regarding the licence profile of the drivers, *11.5%* are professional drivers while the rest *88.5%* has simple driving licence. Out of the 1,274 respondents, *47.7%* holds an academic degree while *25%* holds also a master degree.

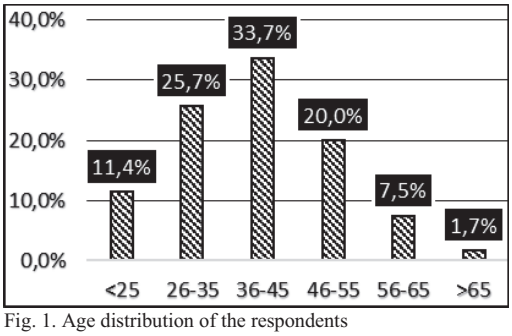

Fig. 1. Age distribution of the respondents

3.2 Drivers' knowledge regarding safety issues

In the first section of the questionnaire, the aim is to examine the drivers' level of knowledge regarding tunnels' safety. Initially, the decision of drivers is examined in case they "are stuck in the tunnel for some time (e.g. due to congestion) without realizing an emergency". Although the majority (65.2%) selects the proper answer, which is to switch off the engine and stay in the car, a significant part believes that they would either stay in the car without switching off the engine (21.4%) or they would get out of the car and stay next to it (12.2%). Both decisions are inappropriate since the first one aggravates the problem of the enclosed tunnel environment with extra emissions, while the second one makes

communication of the control room of the tunnel with tunnel users difficult and increases the risk of being run over by another vehicle when the flow resumes.

Regarding the safety facilities in tunnels, most of the drivers acknowledge the existence of fire extinguishers, emergency exits and emergency telephones in tunnels. But, a significant part of respondents, which is up to 22.5%, 13.7% and 6.7% respectively still seems to ignore these facilities. This knowledge gap can put tunnel users at risk in case of emergency (Kirytopoulos et al., 2017; Zeeri et al., 2019).

Another important finding is the ignorance by 15% of the drivers of the signalling referring to the distance that someone has to travel to reach the closest emergency exit. Especially in case of fire accident, this ignorance can be fatal for the trapped users (Ntzeremes and Kirytopoulos, 2018).

As far as the knowledge of drivers regarding communication channels is concerned, a significant finding is that almost 73.3% of the participants ignore that in some tunnels there is a specific radio frequency that can be used by the tunnel manager in order to inform users in case of an emergency, 63.6% do not know that variable message signs of the tunnel can inform and provide the users with instructions, and 49.4% ignore that loudspeakers are equipment used for this purpose, too. On the other hand, 45.8% do know that emergency telephones can be used to communicate with the control room.

Subsequently, in the case of an emergency in which an one-way tunnel is blocked (e.g. a fire accident), a significant proportion of respondents adopt a dangerous driving behavior. In particular, 19.3% of the drivers believe that they can exit the tunnel by driving in reverse gear to the entrance while 6% believe that they can do a U-turn and continue to drive back to the entrance.

Respondents seem to know how to use the emergency telephones in order to inform the control room, however, *11.3%* of the participants believe that telephone booths can be used as safety shelters in case of a fire accident. This attitude was proven risky in the past, when several users who were trapped in these facilities finally lost their lives (Mont Blanc accident, 1999).

Although about *11.2%* of the participants declare that they may stop inside the tunnel in case of bad weather conditions, participants seem to acknowledge that stopping inside a tunnel is strictly forbidden except from the case that the control room gives such instructions or when there is no other option (e.g. sickness). However, this answer raises serious concerns since respondents' answers previously illustrate their ignorance regarding the communication channels through which the tunnel control room can provide them with instructions.

Social and demographic factors such as age, driving experience and driving frequency inside road tunnels do not affect driving behavior of the current sample. Similar results have been indicated in Zeeri et al. (2019) study. However, previous observations in Greece have observed that driving frequency can affect the driving behavior (Kirytopoulos et al., 2017). This study showcases that the only exception is the gender's influence on the speed limits, as women (*Mean = 4.12*) seem to preserve them more than men (*Mean = 3.58*) do, $U = 7359.2$, $p < 0.05$, $z = -2.032$.

On another note, an important finding is that *82.9%* of the participants believe that they do not receive adequate information on tunnel safety. In particular, *25.9%* states that it has not received any information, while *32.8%* receives "almost never", and *24.2%* "occasionally". The rest *17.1%* states that receives adequate information "often (*7.5%*)", "Very often (*5.7%*)", and only "constantly (*3.8%*)". Furthermore, respondents recognize that leaflets by motorway operators disseminated mainly in toll stations are the only source of information existing in Greece, at the time being. We need to say that this is not the case as there are other forms of communication (especially the internet) but it seems that this is not communicated effectively to the users.

3.3 Driving habits of the tunnel users

The second section of the questionnaire aims to explore declared driving habits of tunnel users by comparing them to their beliefs regarding the behavior of others inside tunnels. Asking the drivers to describe the habits of others helps in identifying the true situation as they do not feel the pressure to reveal unanticipated or wrong habits (Zeeri et al., 2019).

At first, the survey focuses on the drivers' level of compliance with turning on the lights when they enter in a tunnel (Fig. 2).

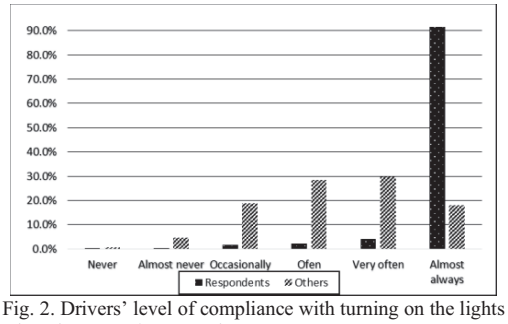

Fig. 2. Drivers' level of compliance with turning on the lights when they enter in a tunnel.

Out of them, *91.6%* declare that they "almost always" turn on the lights, however, they observe that the other drivers do not comply with this aspect. In particular, 18.8% believe that the other drivers "occasionally" turn on the lights while almost 48% do turn on the lights either "often" or "very often". The difference in turning on the lights between respondents (*Mean = 5.85*) and what respondents report that the other drivers do (*Mean = 4.36*) is statistically significant. Wilcoxon test justifies this assumption ($z = -27.649$, $p = .000$).

Regarding drivers' level of avoiding lane hopping inside tunnels, *49.3%* declare that they "never" change lane and *32.9%* declare that they "almost never" do. On the other hand, they believe that *37.4%* of the other drivers do change lanes "often" and *21.8%* "very often". The difference in lane hopping between respondents (*Mean = 1.78*) and what respondents report that the other drivers do (*Mean = 3.98*) is statistically significant. Wilcoxon test justifies this assumption ($z = -30.106$, $p = .000$).

Additionally, only *59.2%* of the participants believe that they comply with speed limits in road tunnels. Meanwhile, *62.6%* realize that the others do not respect the speed limits. Specifically, it was also found that Greek drivers believe that themselves (*Mean = 4.68*) comply more with the speed limits inside road tunnels than the other drivers (*Mean = 3.12*) do, $z = -26.149$, $p = .000$.

Similarly, *85%* of the drivers believe that they maintain greater safety distance, "more than 20m" in the than others do (*52.2%* smaller than 10m). Based on the Wilcoxon test, the difference between respondents (*Mean = 2.27*) and other drivers (*Mean = 1.51*) is statistically significant ($z = -25.866$, $p = .000$).

4. Conclusions

The main goal of this research is to explore the driving behavior of road tunnel users in Greece. It was found that, while participants believe that they adopt safer driving behavior than other users, and they believe that they drive more carefully inside road tunnels than others the results show that there are still things to be learned and that the behaviour of the drivers could be improved as well. All these, should be addressed in the up-coming information campaigns. Despite the fact that the respondents are experienced drivers and that they do use the tunnels often, it seems that the information campaigns implemented so far have not been very successful in reaching a large amount of users or getting the message across.

The differences between how drivers evaluate themselves and how they evaluate the other drivers may illustrate their "true" driving habits and potential behavioral intentions.

The present study is based on 1,274 observations. Since the necessary data was collected by an online questionnaire, unavoidably there are some limitations that should be mentioned. These are issues related to all questionnaire survey studies and include the limited options of provided answers, the likelihood of misinterpretation of the questions and, in this case, the inability to control the sample so that it is fully representative in terms of its distribution among different socio-demographic categories (e.g. age groups).

Regardless of the aforementioned limitations, the size of the sample renders the results significant. The results reflect the Greek drivers' concerns and they highlight the need for better conditions, safety, training and awareness when it comes to road tunnels in Greece.

Tunnel users in Greece need to fully comprehend the importance of adopting the proper behaviour and using the available emergency services to achieve their safety, instead of driving incautiously and acting in panic. A proposal towards providing the necessary road tunnel emergency training is to include such courses to driving schools in Greece. Such courses can include the serious games for safety education. These are video or computer games that present realistic simulations of emergency incidents to the player. As a result, the driver not only gains confidence by facing the safety procedures that need to be followed in a potential similar case, but also understands the importance of road safety, thereby improves his/her driving behavior in order to avoid exposure to such a risk (Vatsvag & Olsen, 2017). Additionally, a proposal can be the contribution of C-ITS services on road safety and driving behaviour that provides I2V & V2I early warning information exchange between drivers and traffic control centers regarding emergency situations.

Further research would include the examination of actual behaviors, instead of perceptions of the drivers.

Acknowledgment

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T1EDK-02374).

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Appendix A*

Table A1. K-S tests. (df = N = 1,274)

Variable	Test Statistic	Asymp. Sig. (2-tailed)
Socio-Demographic variables		
Var(i)	0.516	0.000
Var(ii)	0.179	0.000
Var(iii)	0.526	0.000
Var(iv)	0.254	0.000
Var(v)	0.535	0.000
Var(vi)	0.216	0.000
Var(vii)	0.224	0.000
Drivers' knowledge on tunnel safety issues		
Var(i)	0.396	0.000
Var(ii)	0.518	0.000
Var(iii)	0.500	0.000
Var(iv)	0.460	0.000
Var(v)	0.334	0.000
Var(vi)	0.434	0.000
Var(vii)	0.510	0.000
Var(viii)	0.538	0.000
Var(ix)	0.524	0.000
Driving habits of tunnel users		
Var(i1)	0.520	0.000
Var(i2)	0.190	0.000
Var(ii1)	0.277	0.000
Var(ii2)	0.191	0.000
Var(iii1)	0.234	0.000
Var(iii2)	0.207	0.000
Var(iv1)	0.297	0.000
Var(iv2)	0.356	0.000
Var(v1)	0.311	0.000
Var(v2)	0.222	0.000

*Variables of this Table correspond to the questions presented in Section 2.2.