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A four-country comparative overview of the impact of COVID-19 on traffic safety behavior

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Abstract

The COVID-19 pandemic has had a number of dramatic effects on typical patterns of movement, road crashes and driver behavior. The current research aims to investigate the impact of COVID-19 pandemic on driving behavior and road safety through the exploitation of data from smartphone sensors via smartphone applications developed by OSeven Telematics. A random dataset from its database from 29/12/2019 to 31/12/2020 for four countries (i.e. Greece, Saudi Arabia, Cyprus and Brazil) was analyzed. Results demonstrated that average driving speed, speeding percentage and harsh events (except for Cyprus) were increased during the lockdown period. A reduction in traffic volume and numbers of people walking in each country was also identified. The effectiveness of COVID-19 pandemic massive measures for controlling the spread of the disease can be an excellent example for massive measures for the improvement of road safety, everywhere in the world.

Keywords: *COVID-19 pandemic; traffic volumes; driving behavior; road crashes; descriptive analysis.*

Περίληψη

Η πανδημία του κορωνοϊού έχει επιφέρει μια σειρά από σημαντικές αλλαγές στην κυκλοφορία, τα τροχαία ατυχήματα και την οδηγική συμπεριφορά. Στόχος της παρούσας έρευνας είναι ο προσδιορισμός των επιπτώσεων του κορωνοϊού στην οδηγική συμπεριφορά και την οδική ασφάλεια μέσω της εκμετάλλευσης δεδομένων από αισθητήρες κινητών τηλεφώνων που λαμβάνονται από εφαρμογές κινητών τηλεφώνων οι οποίες αναπτύχθηκαν από την εταιρία τηλεματικής OSeven. Αναλύθηκε ένα τυχαίο σύνολο δεδομένων από 29/12/2019 έως 31/12/2020 για τέσσερις χώρες (Ελλάδα, Σαουδική Αραβία, Κύπρος και Βραζιλία). Τα αποτελέσματα έδειξαν ότι η μέση ταχύτητα οδήγησης, το ποσοστό υπέρβασης του ορίου ταχύτητας και τα απότομα συμβάντα (εκτός από την Κύπρο) αυξήθηκαν κατά τη διάρκεια των περιοριστικών μέτρων. Επίσης, παρατηρήθηκε μείωση της κυκλοφορίας οδηγών και πεζών σε κάθε χώρα. Η αποτελεσματικότητα των μέτρων για τον περιορισμό της εξάπλωσης της νόσου μπορεί να αποτελέσει εξαιρετικό παράδειγμα για τη λήψη δραστικών μέτρων για τη βελτίωση της οδικής ασφάλειας, παντού στον κόσμο.

Λέξεις κλειδιά: *κορωνοϊός, κυκλοφορία οδηγών και πεζών, οδηγική συμπεριφορά, τροχαία ατυχήματα, περιγραφική ανάλυση.*

1. Introduction

In the year 2019, the first confirmed cases of COVID-19 were identified in Wuhan, Hubei Province, China (Zhu et al., 2020). Since then, normal daily lives have radically altered across the globe (Lu et al., 2020) and consequently, affected typical patterns of travel activities and movements in urban regions (Kim, 2021). As a result, many researchers are struggling to explore the dynamics of the pandemic in several countries worldwide in order to understand the impact that COVID-19 had on road safety (Sharifi & Khavarian-Garmsir, 2020).

Existing studies have revealed that there was a great change in modal choice patterns and, therefore, in driving and walking volumes. After the restrictive measures implemented by governments to help mitigate the spread of the disease, an unprecedented reduction in global traffic volumes was identified. Indicatively, Bucsky (2020) revealed that COVID-19 restrictions reduced mobility by half in Budapest, Hungary; modal share of public transport also decreased dramatically. Furthermore, in the Netherlands, roughly 80% of people reduced their outdoor activities due to the pandemic, leading to a 55% decline in the total number of trips and 68% reduction in distance travelled, with the proportion of people that were working from home increasing from 6% to 39% (de Haas et al., 2020). During the lockdown period, and due to travel restrictions, there was a statistically significant reduction in vehicle miles driven and driving days per week (35% and 37% respectively), in the month of April 2020 compared to the normal period before the appearance of the COVID-19 pandemic (Stavrinos et al. 2020).

The restrictions on travel and business activities have also fostered certain changes in driver behavior. Specifically, Katrakazas et al. (2020) identified reductions in driving and walking volumes in Greece and Saudi Arabia. At the same time, increased travel speeds (6–11%), with more frequent harsh accelerations and braking per distance were detected. Additionally, a slightly increase (i.e. only by a few mph) on maximum and average driving speed was identified in certain highways in California (Shilling &Waetjen, 2020). Interestingly, in three major cities in Ohio, drivers were more willing to exceed the speed limits and drive faster on the empty roads, making streets and highways potentially more dangerous (Lee et al., 2020). Another innovative research quantified the effect of COVID-19 pandemic on driver behavior using SARIMA time-series modelling. Results indicated that the observed values of three driving performance indicators (i.e. average speed, speeding and harsh brakings per 100km) were higher compared to forecasts based on their corresponding observations before the first lockdown in Greece (Katrakazas et al., 2021).

During the COVID-19 lockdown measures, the number of road crashes and traffic fatalities has decreased significantly, especially during the first months of 2020. In particular, large reductions in road crashes (74% compared to February of 2020; 76% compared to 2019) were identified in the Tarragona Province of Spain (Saladié et al., 2020). This can probably be attributed to the overall reduction in travel volumes (roughly 63%). Similarly, Carter (2020) demonstrated that during the COVID-19 lockdown period (i.e. from March 15, 2020 to May 16, 2020), the total number of crashes in North Carolina was decreased by 50%, fatalities were decreased by 10%, while serious injuries were increased by 6%, compared to pre-lockdown baseline. Shilling & Waetjen (2020) indicated reduced numbers of road crashes, including

injury/fatal crashes on state highways and rural roads, while a great decline in road fatalities was observed with decreasing work-related trips (Gupta et al., 2021). However, on a macroscopic population scale, it should be noted that the overall mortality reductions originating from road crashes were more than offset by increased deaths due to COVID-19 pandemic (Colonna & Intini, 2020).

The unprecedented impact of the pandemic on daily travel behavior, the scarcity of studies focusing on correlating the coronavirus disease with road safety as well as the variation of COVID-19 countermeasures globally form the motivation for the current research, which aims at exploring the impact of COVID-19 pandemic on driving behavior and road safety during 2020 in various countries, namely: Greece, Saudi Arabia, Cyprus and Brazil. To achieve this objective, a descriptive exploration of 12 months of data regarding, traffic volumes, driving behavior indicators (i.e. speeding percentage, average driving speed, harsh accelerations/100km, harsh brakings/100km, total duration, driving duration) as well as road crashes were analyzed.

Undoubtedly, driving performance indicators and traffic exposure data from previous years would be beneficial in order to take into account the seasonality trends, make comparisons and support our findings. Nevertheless, data were available only for 2020; thus, an attempt was made to draw some useful insights and main conclusions based on the data available (i.e. before and after the lockdown periods in each country).

The paper is structured as follows: initially, the literature with regards to driving behavior and road safety during the pandemic is reviewed. This is followed by an overview of the data needed for the exploratory analysis. The main part of this paper is dedicated to depict the changes in driving behavior during 2020 and is followed by a section on weekly pattern identification. Finally, the findings are discussed and conclusions for researchers and practitioners are also provided.

2. Data Collection

For the purpose of this study, OSeven provided a random dataset from its database from 29/12/2019 to 31/12/2020 for four countries (i.e. Greece, Saudi Arabia, Cyprus and Brazil). Descriptive statistics, both before and after the appearance of COVID-19 in the aforementioned countries, were estimated in order to examine whether driving or walking traffic volumes, road crashes and driving performance indicators have been changed. It should be noted that geographical differences among the four countries examined were not taken into consideration, as detailed location data were not provided and spatial analysis did not take place.

Data from smartphone sensors (e.g. GPS, accelerometer data, and gyroscope data) were collected using the smartphone applications and platform developed by OSeven Telematics (https://oseven.io/). A set of sophisticated and personalized interactive tools was applied, powered by data fusion technology, machine learning algorithms and driver monitoring metrics. For each trip completed, a large amount of data was recorded, transmitted through

WiFi or cellular network and valuable critical information such as features, highlights and driving score was produced in order to evaluate driving profile and performance. Subsequently, data were sent to the OSeven backend infrastructure where there were evaluated using filtering, signal processing, machine learning algorithms and safety/eco scoring models.

It is worth highlighting that OSeven platform has clear privacy policy statements and follows strict information security procedures, in compliance with the General Data Protection Regulation (GDPR) and related EU directives. Thus, all data has been provided by OSeven in a completely anonymized format and no geolocation information for the trips (apart from the related country) have been included in the dataset. The driving indicators included in the present analysis are presented in Table 1.

Table 1: *Description of the driving indicators of the analysis (Source: OSeven)*

Indicator	Unit	Description
Total distance	km	Total trip distance
Driving duration	sec	Total duration of driving (i.e. duration of stops has been excluded)
Harsh accelerations/100km	-	Number of harsh accelerations per distance (i.e. 100 km)
Harsh brakings/100km	-	Number of harsh brakings per distance (i.e. 100 km)
Average driving speed	km/h	Average speed during driving with stops been excluded from the duration of the trip
Speeding percentage	%	Ratio of duration of speeding in a trip per total duration of driving (i.e. duration of stops has been excluded)

In order to be able to provide an overview of the COVID-19 impact on driving and walking patterns, the mobility data reports from Apple (Apple, 2020) were used, as a proxy of the traffic activities for three of the four examined countries (i.e. Greece, Saudi Arabia and Brazil); traffic volume data for Cyprus were not available. The aggregated data collected from Apple show the mobility trends for major cities and several countries or regions. The information is generated by aggregating the number of requests made to Apple for directions. The data sets are then compared to measure changes in volume of people driving, walking or taking public transit globally. Data availability in a particular city, country, or region is subject to a number of factors, including minimum thresholds for direction requests made per day.

With regards to the evolution of cases and casualties from COVID-19 pandemic as well as the response measures, data were retrieved from the national ministries of health (especially for Greece) and were cross-checked with governmental press releases and popular webpages counting the spread of COVID-19 (e.g. Hale et al., 2020; Worldometer, 2021; Johns Hopkins Coronavirus Resource Center, 2021). Table 2 summarizes the lockdown periods of non-essential movements due to COVID-19 pandemic that have been announced by the government of each country.

Table 2: *Periods of lockdown of non-essential movements in Greece, Saudi Arabia, Cyprus and Brazil (Worldometer , 2021)*

Greece	
1st Lockdown of non-essential movements	23/03/2020-04/05/2020
2nd Lockdown of non-essential movements	07/11/2020-31/12/2020
Saudi Arabia	
Lockdown of non-essential movements	09/03/2020-21/06/2020
Cyprus	
Lockdown of non-essential movements	24/03/2020-21/05/2020
Brazil	
Lockdown of non-essential movements	20/03/2020-10/05/2020

Lastly, high-quality data on total number of road crashes, fatalities, severe and slight injuries were available only for Greece, derived from the Hellenic Statistical Authority (ELSTAT) and cover a one-year timeframe from January 2020 to December 2020. The chosen time period contained two months with normal operations before the appearance of COVID-19 pandemic (i.e. January-February 2020), as well as the months of the COVID-19-induced lockdown periods in Greece. Thus, a comparison between countries cannot be drawn and relevant remarks for road safety will be extracted only for Greek drivers.

3. Results

3.1 Traffic volumes

From the beginning of March, and especially after the initiation of the lockdown in the middle of the month, a 62% reduction of people driving and a 58% reduction of people walking was observed in Greece. After the end of the first lockdown, driving and walking volumes were increased at a steady rate. Empirically, Greece displayed high congestion levels throughout the summer. Traffic started to rise significantly during August 2020 when the peak-time congestion on Greece's roads registered a 400% increase compared to the first lockdown. Interestingly, during the second lockdown period, driving traffic volumes were elevated considerably, roughly by 91% than the first one. It was revealed that more people were using individual means of transport (i.e. cars) and more walking, jogging and other physical activities were identified. Lastly, walking traffic volumes were decreased by 60% compared to the period between the first and the second lockdown.

With regards to Saudi Arabia, a 56% reduction for driving and a 47% reduction for walking was observed. After the lockdown, people walking and driving reverted immediately to baseline frequencies. In particular, when the curfew was lifted throughout the country, driving traffic volumes started to increase significantly and an 82% rise was observed compared to the period of the first lockdown. At the same time, after the end of the lockdown period, the volume of people walking was increased by 64%.

Similar reductions in traffic volumes were also demonstrated in Brazil. During the lockdown period, a 63% reduction of people driving as well as a 56% reduction of people walking was observed compared to the baseline. Afterwards, driving and walking patterns increased at a steady rate. After the end of the lockdown period, a 55% increase in driving volumes as well as a 47% spike on walking patterns was identified compared to the lockdown period.

Figure 1 demonstrates the corresponding driving and walking volumes from January to December 2020 with the evolution of COVID-19 cases in Greece, Saudi Arabia and Brazil. It is worth mentioning that the dashed baseline refers to the average figures for the months before the appearance of COVID-19 (i.e. under normal driving circumstances).

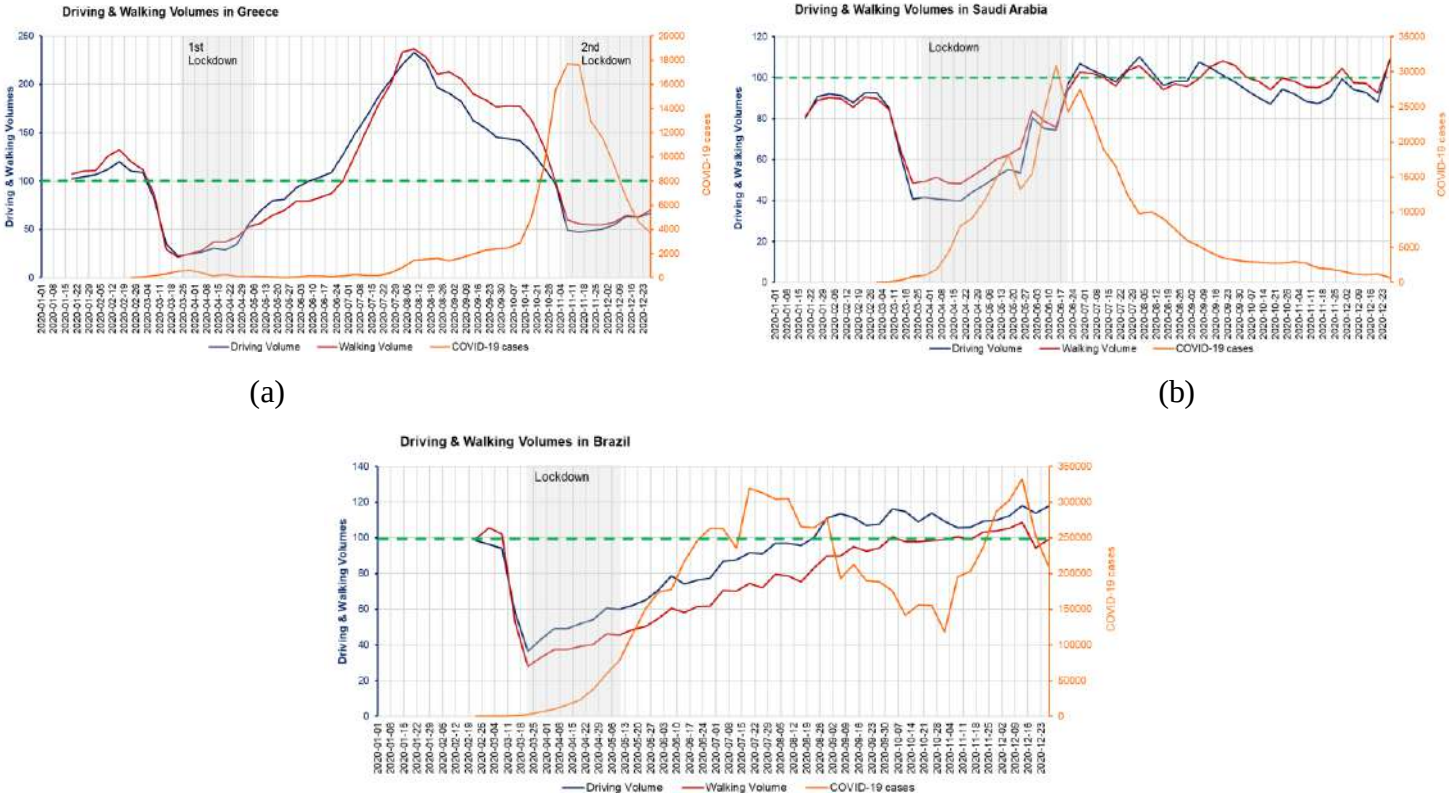


Figure 1: *Traffic volumes per week along with the evolution of COVID-19 cases (a) Greece, (b) Saudi Arabia, (c) Brazil (Source: Apple)*

3.2 Driving behavior

The COVID-19 pandemic had a direct effect on active drivers on the roads across countries. Following the patterns of traffic volumes, the second wave of COVID-19 pandemic led to a 10% reduction in total distance driven in Greece compared to the first one. When the restrictions on movements and business activities were gradually lifted, total distance increased in response. Specifically, a 18% increase in total distance travelled in March and April was found in contrast

to the period between the first and the second lockdown (i.e. from May to early-November 2020). At the same time, during the second lockdown period in Greece (i.e. in November and December 2020), total distance driven per trip was reduced by 23% compared to the period between the first and the second lockdown (i.e. from May to early November).

Similar patterns were also identified in Saudi Arabia. During the lockdown period, a 18% reduction in total distance driven per trip was identified. After the end of the lockdown period, a 13% increase in miles driven was observed when comparing data from March to June (i.e. COVID-19 lockdown period) with data from the end of June to December 2020 (i.e. after the end of lockdown of non-essential movements).

Both in Cyprus and Brazil, total distance was reduced due to the lockdown restrictions. In particular, during the lockdown period, a 9% decrease total distance was identified in Cyprus compared to the period before the appearance of COVID-19 pandemic. When the non-essential measurements were lifted, a 17% increase in total distance driven per trip was observed. Taking into account the restrictions in Brazil, during the lockdown period, a 26% reduction was found compared to the before period. However, total distance was increased by 9%, when Brazil began to gradually remove restrictions on movement and restart business activities.

Figure 2 illustrates the changes in total distance driven per trip in Greece, Saudi Arabia, Cyprus and Brazil.

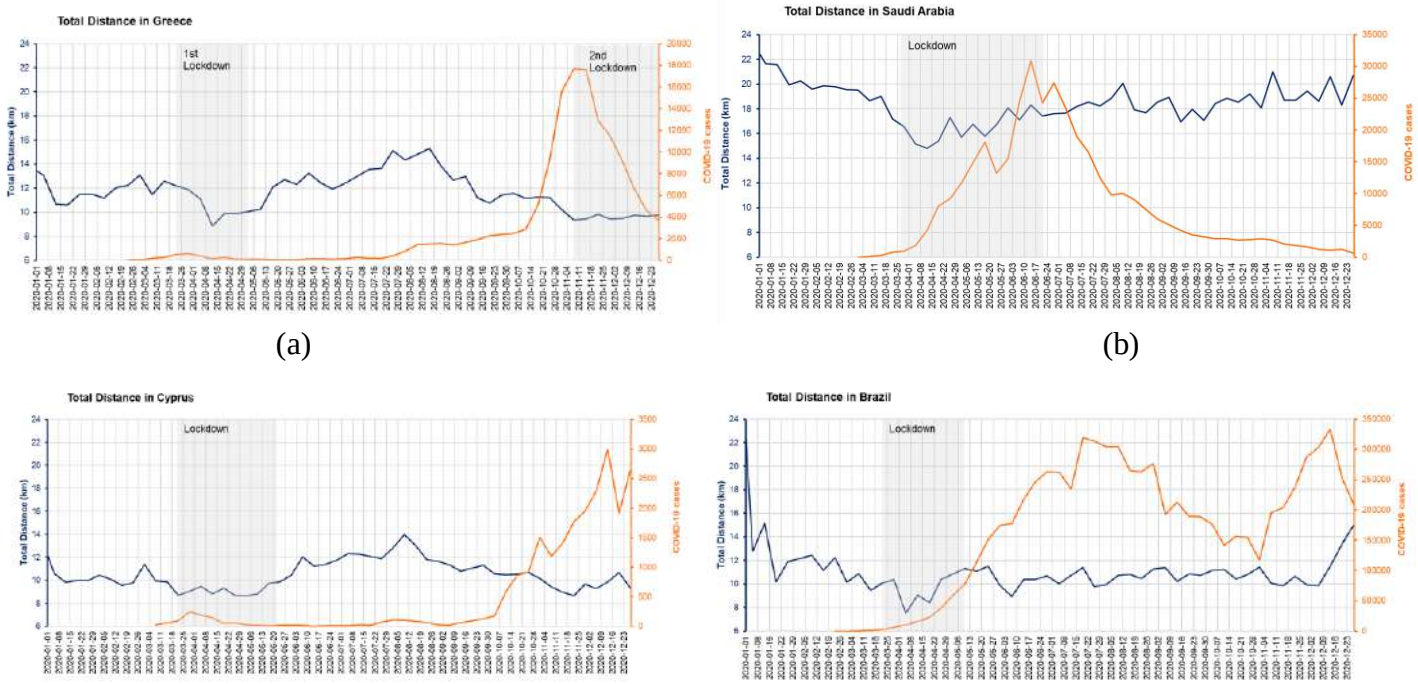


Figure 2: *Total distance per week along with the evolution of COVID-19 cases (a) Greece, (b) Saudi Arabia, (c) Cyprus (d) Brazil (Source: OSeven)*

Apart from the aforementioned indicator of total distance, COVID-19 pandemic and lockdown restrictions had also a great impact on driving duration, as shown in Figure 3. Firstly, during the first lockdown period, a 15% decrease in driving duration was identified in Greece compared to the first two months of 2020 (i.e. January-February). Interestingly, during the second lockdown period, a 2% decline in driving duration was identified in Greece compared to the first one. Additionally, during the second lockdown period (i.e. November and December 2020), a 19% reduction was found compared to the period between the first and the second lockdown. However, driving duration was increased by 21%, when Greece began to gradually lift restrictions on movement and restart business activities.

Regarding Saudi Arabia, during the first lockdown period, a 21% reduction in driving duration was identified compared to the period before the appearance of COVID-19 pandemic. After the end of the lockdown period, a 12% increase in driving duration was observed. During the lockdown period in Cyprus, driving duration has dropped roughly by 10% compared to the period before the appearance of COVID-19 pandemic. When the restrictions on movements and business activities were gradually lifted, driving duration was increased by 14%. Finally, the total number of driving trips in Brazil were significantly reduced by 22% due to the lockdown period. After the end of the lockdown, more vehicles on city streets were observed; thus, a 9% rise in driving duration was identified.

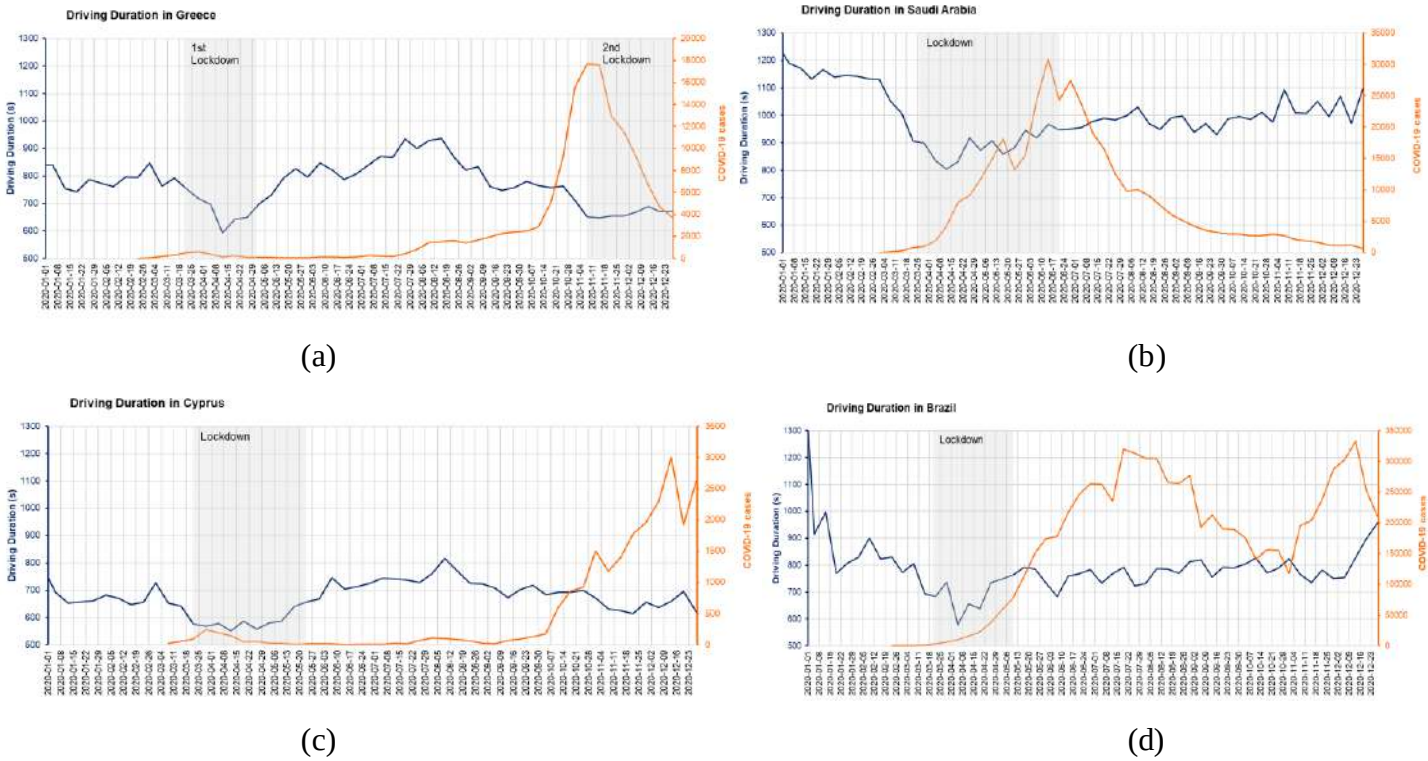


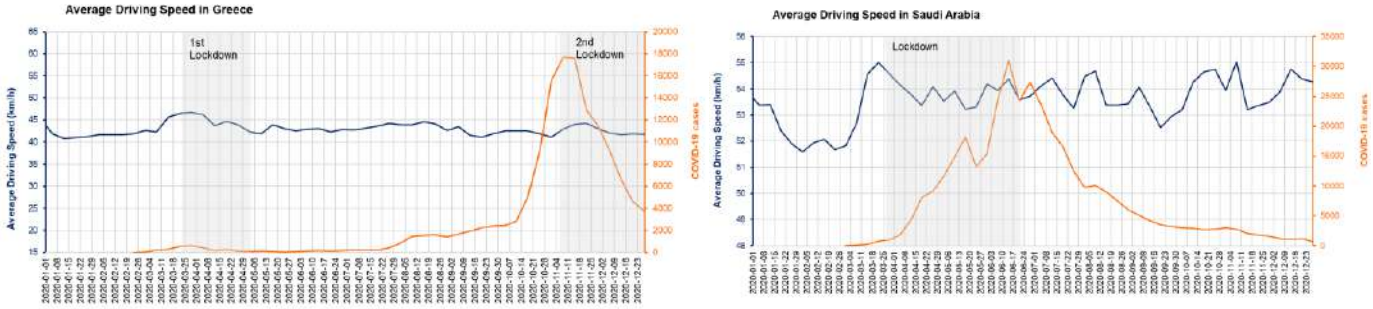
Figure 3: *Driving duration per week along with the evolution of COVID-19 cases (Source: OSeven) (a) Greece, (b) Saudi Arabia, (c) Cyprus (d) Brazil (Source: OSeven)*

It should be noted that during the first and second lockdown period in Greece, an overall increase in average driving speed was identified compared to the period between the two lockdown periods (i.e. from May to early November 2020). To begin with, during the first lockdown period in Greece, a 7% spike in average driving speed was identified compared to a normal period in January-February 2020. When the restrictions on non-essential movements were gradually lifted, average driving speed gradually began to raise, but with more vehicles on city streets, drivers reduced their overall average speed by 5%, even when the restrictions of non-essential movements were dropped. During the second lockdown period, a 5% decrease in average speed was identified in Greece compared to the first one. Moreover, it is worth mentioning that no change in average driving speed was identified during the second lockdown compared to the period between the first and the second lockdown (i.e. from May to early-November).

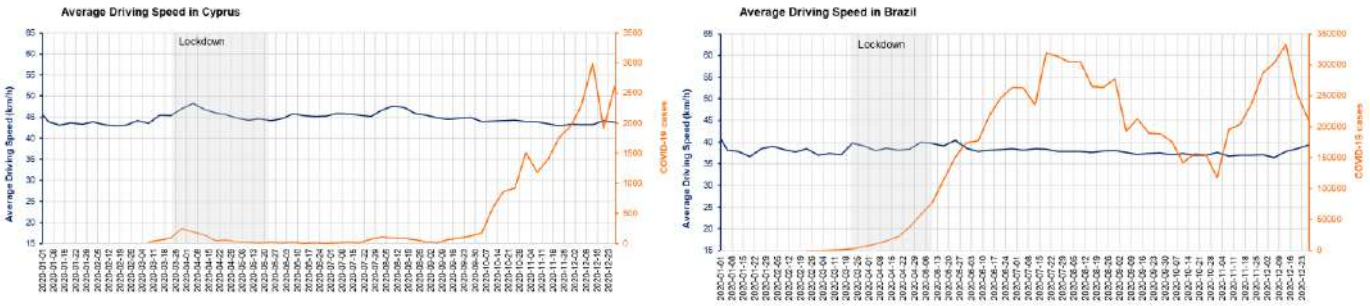
With regards to Saudi Arabia, during the lockdown period, a negligible 2% increase in average driving speed was identified compared to the period before the appearance of COVID-19 pandemic. After the end of the lockdown, no change in average driving speed was found, when comparing data from March to June (i.e. COVID-19 lockdown period) with data from end-June to December (i.e. after the end of lockdown of non-essential movements).

Similarly, during the lockdown period in Cyprus, a 4% increase in average driving speed was identified compared to the period before (January-February 2020), and then, drivers managed to reduce their average driving speed (roughly by 1%) compared to the lockdown period. Lastly, both during and after the lockdown period in Brazil, no significant change was detected on average driving speed compared to a normal period (i.e. before the appearance of COVID-19).

It is worth mentioning that the highest values of average driving speed were identified during August 2020 for all countries. This finding seems reasonable as these days refer to summer holidays, when reduced traffic volumes lead to higher average driving speeds. Figure 4 shows evidence of average driving speed, especially, during and between the lockdown periods in Greece, Saudi Arabia, Cyprus and Brazil.



(a) (b)



(c) (d)

Figure 4: *Average driving speed per week along with the evolution of COVID-19 cases (a) Greece, (b) Saudi Arabia, (c) Cyprus (d) Brazil (Source: OSeven)*

Overall, the ratio of speeding duration/driving duration was changed in a great extent due to the lockdown restrictions. Specifically, during the first lockdown period, a 22% increase in speeding percentage was identified in Greece compared to the period before the appearance of COVID-19 pandemic. Additionally, during the second lockdown period, a 2% reduction in speeding percentage was observed in Greece, compared to the first one. After the end of the first lockdown period, a 9% drop in speeding percentage compared to the period between the first and the second lockdown was identified. Furthermore, the ratio of speeding duration/driving duration was increased by around 8% in November and December after the second lockdown had been announced compared to the period before (i.e. between the first and the second lockdown from May to early November).

Similar to speeding percentage indicator in Greece, the ratio of speeding duration/driving duration was also increased in the other three countries. More specifically, the speeding ratio was increased by 17% during the lockdown in Saudi Arabia, by 22% in Cyprus and by 15% in Brazil. Interestingly, after the end of the lockdown period, a 23% drop was identified in Saudi Arabia and an 11% decrease in Cyprus, while in Brazil there was no significant change. Figure 5 illustrates the fluctuations in the ratio of speeding duration per driving duration in the four countries.

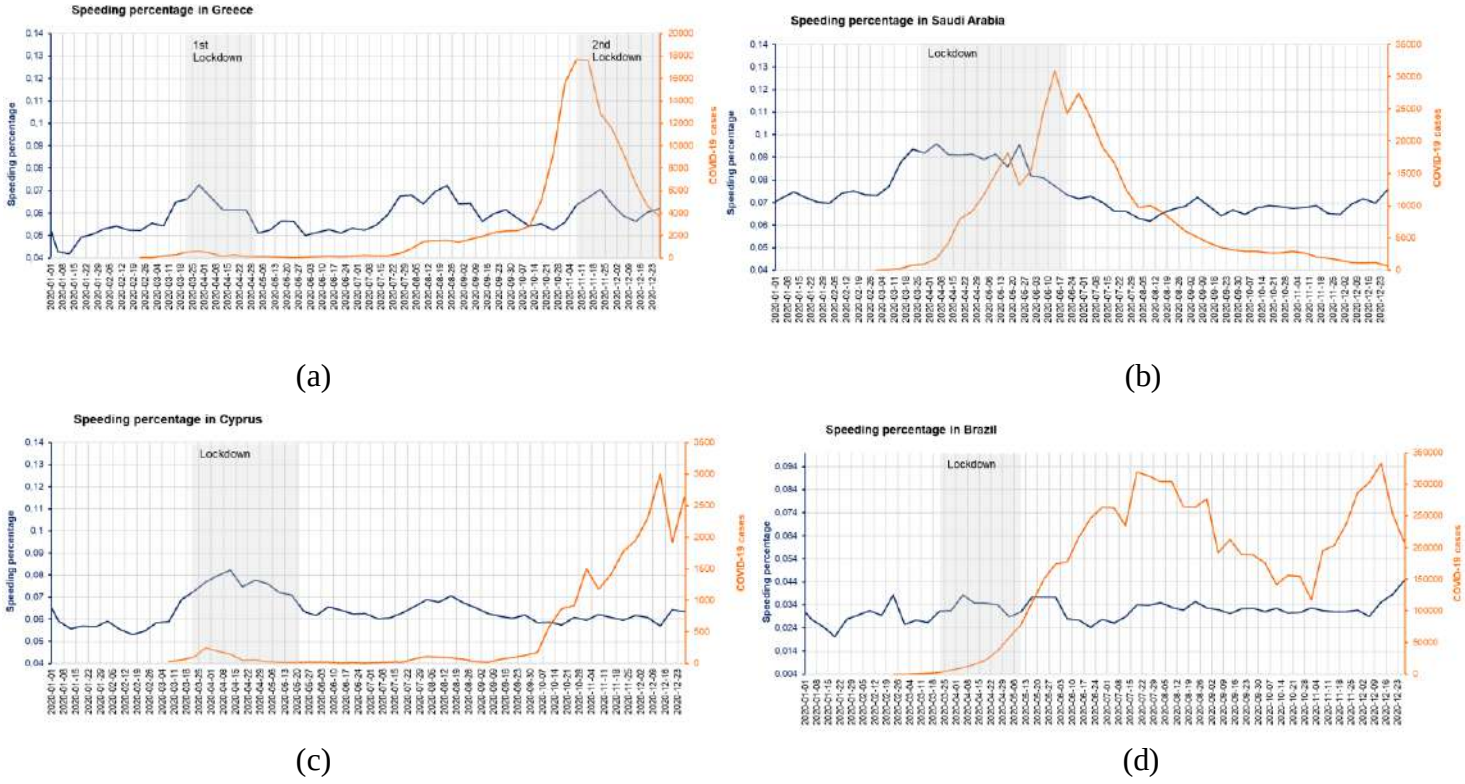


Figure 5: *Speeding percentage per week along with the evolution of COVID-19 cases (a) Greece, (b) Saudi Arabia, (c) Cyprus (d) Brazil (Source: OSeven)*

It should be noticed that the COVID-19 pandemic had a great impact on harsh driving events per distance travelled. In Greece, during the first lockdown period and especially in April 2020, harsh accelerations per 100km were increased by 5% compared to January-February 2020 (i.e. before the appearance of COVID-19 pandemic). During the second lockdown period, a 17% decrease in harsh acceleration events per distance travelled was found in Greece compared to the first one. When the restrictions on movements and business activities were gradually lifted, harsh accelerations per 100km were again dropped by 18% compared to the first lockdown period. Interestingly, a negligible 2% spike in harsh accelerations per 100km was identified during the second lockdown compared to the period between the first and the second lockdown.

In the case of Saudi Arabia, it was revealed that drivers accelerated harshly, especially during the months of COVID-19. Overall, during the lockdown period, an 11% spike in harsh acceleration events per distance was observed compared to the period before. After the end of the lockdown period, a 34% decrease in harsh accelerations per 100km and fewer harsh accelerations per distance were identified, which indicates that drivers had improved their driving performance after the COVID-19 pandemic.

Similar trends were observed for Brazil as well. In particular, the increase in harsh acceleration events was evident after the lockdown initiation in Brazil, as streets were emptier. During the lockdown period, harsh accelerations per 100km were increased by 15% compared to the period before the appearance of COVID-19 pandemic. Afterwards, a 4% decrease in harsh accelerations per distance travelled was identified.

However, in Cyprus, both during and after the lockdown period, a 6% and 7% reduction in harsh acceleration events per distance was observed compared to the period before and the lockdown period, respectively. This fact probably denotes that traffic volumes in Cyprus were similarly increased before and after the lockdown period, and therefore harsh events did not increase as it would happen with emptier roads. The vast differences of Cyprus, which is a small island nation, with the larger networks of the other countries should also be taken into account.

Regarding Greece, similarly with harsh accelerations, harsh braking frequency per 100km was increased during the first days of January, while in the following days, a reduction was identified. To begin with, during the first lockdown period harsh brakings per 100km were increased by 11% compared to the first two months of 2020 (i.e. before the appearance of COVID-19 pandemic). When Greece began to gradually lift restrictions on movement and restart business activities, harsh brakings per distance were dropped by 33% compared to the first lockdown period (i.e. March and April 2020), while there was a 10% increase in harsh brakings per 100km during the second lockdown period compared to the period between the first and the second lockdown.

Comparably, in Saudi Arabia, during the lockdown period, a 7% increase in harsh brakings per 100km was identified compared to the period before the appearance of COVID-19 pandemic. After the end of the lockdown period, a 23% reduction in harsh braking events per distance was revealed. A similar increase followed by a decrease between the lockdown and the period after was revealed for drivers in Brazil. More specifically, a 10% spike in harsh braking events per 100km was identified during the lockdown and a 15% decrease in harsh brakings per distance was observed after the restrictions.

As far as Cyprus is concerned, harsh brakings per 100km were decreased by 6% during the lockdown period, compared to the period before. Moreover, a 18% reduction was also identified after the end of the COVID-19 restrictions compared with the lockdown period. This is a similar finding with the one about harsh accelerations, and might be a result linked with traffic volumes during the COVID-19 period in Cyprus.

Figure 6 depicts the changes in harsh events per week along with the evolution of COVID-19 cases per 100km in Greece, Saudi Arabia, Cyprus and Brazil.

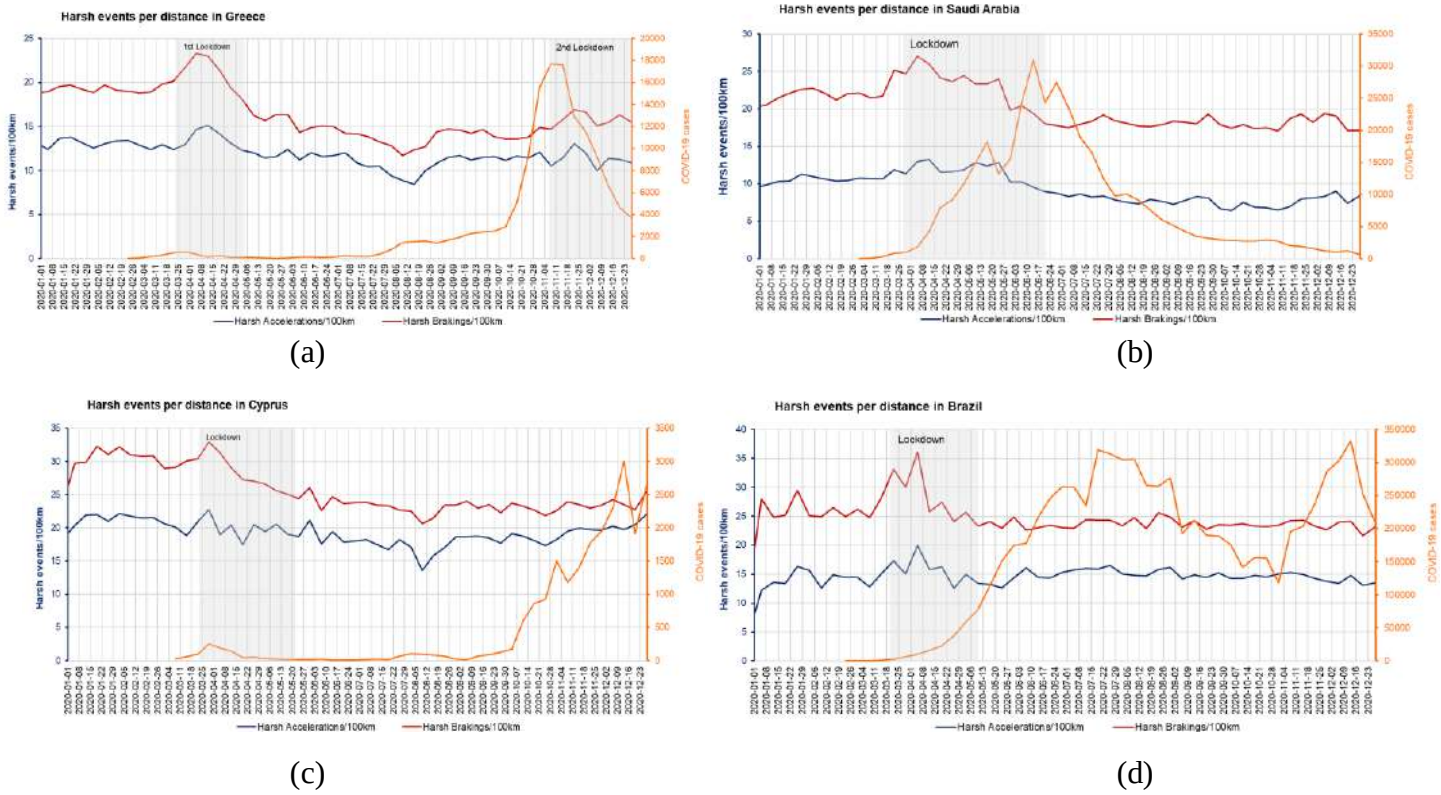


Figure 6: *Harsh events per week along with the evolution of COVID-19 cases (a) Greece, (b) Saudi Arabia, (c) Cyprus (d) Brazil (Source: OSeven)*

3.3 Road crashes

A more comprehensive picture of the impact of COVID-19 pandemic on road safety can be drawn from the high-quality data on total number of road crashes. For Greece in particular, during the first lockdown period, a 49% decrease in the total number of road crashes was observed compared to the period before the appearance of COVID-19 pandemic (i.e. January-February 2020). Afterwards, during the second lockdown period, a 46% increase in road crashes was identified compared to the first one. After the end of the first lockdown period, driving volumes were gradually increased and a 116% rise in the total number of road crashes was observed in the period between the first and the second lockdown compared to the first lockdown period. Interestingly, a 32% reduction in road crashes was recorded during November 2020 (i.e. during the second lockdown) compared to the period before (i.e. between the first and the second lockdown from May to early-November). Lastly, it should be noted that monthly data for road crashes are available only for Greece, while there is no evidence for road crashes in Saudi Arabia, Cyprus and Brazil during 2020 as of the writing of the present research.

Figure 7 depicts the changes in the total number of road crashes along with the evolution of COVID-19 cases from January to December 2020 in Greece.

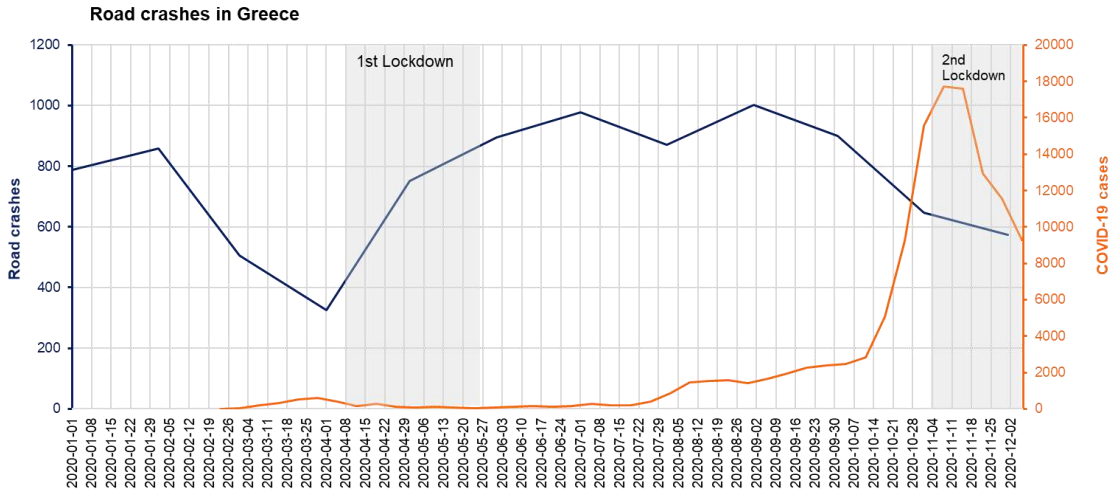


Figure 7: *Road crashes along with the evolution of COVID-19 cases in Greece (Source: ELSTAT)*

4. Conclusions

This paper presented an investigative approach aiming to quantify the impact of the COVID-19 pandemic on driving behavior using naturalistic driving data smartly obtained from smartphone sensors in four countries (i.e. Greece, Saudi Arabia, Cyprus and Brazil). The evaluation of the impact of COVID-19 was based on descriptive statistics for several driving performance indicators (i.e. speeding percentage, average driving speed, harsh accelerations per 100km, harsh brakings per 100km, total duration, driving duration) based on the period before and after the coronavirus spread for each country.

Results demonstrated that during the lockdown period, the majority of driving performance indicators (e.g. average driving speed, ratio of speeding duration per driving duration) were increased compared to the period before the appearance of COVID-19 pandemic. This was due to the fact that with fewer vehicles on city streets, more drivers found increased temporal and spatial headways and were not respecting the speed limits; accordingly, more harsh events per distance travelled occurred. In addition, harsh events such as harsh accelerations per 100km and harsh brakings per 100km (except for Cyprus) were elevated during the COVID-19 restrictions. This was probably due to the fact that, given emptier roads, drivers tended to increase their speed more and accelerated or braked suddenly when an obstacle or pedestrian was observed.

It was evident that the dissolution of imposed lockdowns led to an increase in traffic volumes, but also to smoother driving behavior. A reduction in traffic volume and people walking in each country was identified. At the same time, data showed that when lockdown states were lifted,

a dramatic change in traffic volumes by up to 400% in Greece was observed. In Saudi Arabia the corresponding change rose to 82%, an increase which is still considerably high, while in Brazil, driving volumes increased by up to 55%. Following the same pattern, traffic volumes were substantially increased when comparing the first and second lockdowns. This finding is interesting when put into the perspective of the stringency of response measures and COVID-19 cases and casualties, since the lockdown periods (i.e. the first and second lockdown in Greece as well as the single lockdown in the KSA) are characterized by strict measures and a high number of COVID-19 cases and casualties. As a result, it can be tentatively assumed that drivers adjusted to these new conditions and behaved as if no restrictions were applied.

With regards to Greece, during the traffic lockdown periods due to the COVID-19 pandemic, the number of road crashes decreased significantly, mainly due to the dramatic traffic decrease. It is highly important that during the COVID-19 period as well as shortly after, the national health systems are not further overloaded by road casualties. Therefore, this is an opportunity to place efficient traffic safety measures as soon as possible, to prevent traffic crash rates from rising again.

In the current research, the focus was placed on comparing the differences among driver-related indicators instead of investigating the different types of geographical characteristics and road network. To that end, trip data were collected from a specific subset of the population of Greece, Saudi Arabia, Cyprus and Brazil (i.e. users of OSeven mobile phone application). Future scientific investigations may explore the presence of statistically significant effects present at the level of population subsets (e.g. in the form of mixed-effects modelling) or at the level of geographical units across countries (e.g. spatial effects).

The effectiveness of the temporary COVID-19 pandemic massive measures for controlling the spread of the disease can be an excellent example for the need of more serious and massive measures on the constantly present road safety ‘pandemic’. A more in-depth understanding of how the pandemic has affected road safety, and how a gradual re-opening and possible subsequent restrictions may affect driver behaviors, still needs to be determined. Close attention must be paid to these indicators which are newly available from technological advances to determine if there is a continued effect of pandemic restrictions on road safety.

All in all, the pressure that COVID-19 is placing for installations of temporary or permanent infrastructure enabling more pedestrians and cyclists to meet physical distancing recommendations is a positive byproduct of this unprecedented crisis. From a road safety and transportation engineering perspective, safer road traffic and no crashes during and after the COVID-19 pandemic consist the first priority. Safer driver performance and no road crashes during and after the pandemic consist the first priority and the COVID-19 crisis can be the trigger for authority actions and for responsible behavior of citizens for safer roads for all, everywhere in the world.

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