A descriptive analysis of the effect of the COVID-19 pandemic on driving behaviour and road safety

Christos Katrakazas[1]*, Eva Michelaraki[1], Marios Sekadakis[1], Petros Fortsakis[2], George Yannis[1]

[1]National Technical University of Athens, Department of Transportation Planning and Engineering, 5 Heroon Polytechniou str., GR-15773, Athens, Greece

[2]OSeven Single Member Private Company, 27B Chaimanta Str., GR-15234, Athens, Greece

* Corresponding author

Abstract

The spread of the new coronavirus COVID-19, has led to unparalleled global measures such as lockdown and suspension of all retail, recreation and religious activities during the first months of 2020. These measures undoubtedly had an immediate effect on everyday driving behaviour and the level of road safety. Nevertheless, no scientific evidence has been reported so far with regards to this impact. This paper investigates the effect of COVID-19 on driving behaviour and safety indicators captured through a specially developed smartphone application and transmitted to a back-end platform. These indicators are reflected with the spread of COVID-19 and the respective governmental countermeasures in two countries, namely Greece and Saudi Arabia, which had the most completed routes for users of the smartphone applications. It was shown that reduced traffic volumes due to lockdown, led to a slight increase in speeds by 4-7%, but more importantly to more frequent harsh acceleration and harsh braking events (up to 12% increase) during March and April 2020, which were the months where COVID-19 spread was at its peak. On the bright side, accidents in Greece were reduced by 41% during the first month of COVID-19-induced measures, mobile phone use dropped by 65% and driving in the early morning hours (00:00-05:00) which are considered dangerous dropped by up to 81%. Policymakers should concentrate on establishing new speed limits and ensure larger spaces for cycling and pedestrians in order to enlarge distances between users. Such measures will safeguard both an enhanced level of road safety and the prevention of COVID-19 spread, which will prove beneficial for the function of health systems and societies in general.

1 Introduction

COVID-19, a novel coronavirus initially diagnosed in patients in Wuhan, China in December 2019 (Zhu et al., 2020), was declared a pandemic from the World Health Organization (WHO) on the beginning of March 2020 (WHO, 2020). As of May 2020, more than 3.5 million people have been infected by the virus with fatalities raising up to 247.000. In a span of nearly five months, COVID-19 has changed dramatically living conditions for the entire globe.

The most popular countermeasure to the spread of COVID-19 imposed by the majority of countries was a "lockdown" restricting everyday life activities to only the most essential and prohibiting people from leaving their residential

premises. As a result, rapid changes in societal and financial patterns have been widely observed (Anderson et al., 2020; Zhang et al., 2020).

With the majority of the global population on a "lockdown" status, road traffic volumes and mobility activities in general have immensely dropped (Clarke, 2020; Google LLC, 2020). The reduction of traffic volumes moving on road infrastructure, evidently reduces their exposure to another important health problem, namely road traffic accidents. Traffic collisions kill approximately 1.35 million people and injure up to another 50 million people each year (WHO, 2018), rates that are comparable to the current COVID-19 in perspective. However, to-date the effect of COVID-19 induced lockdowns on driving behavior has not been evaluated.

The lack of quantified evaluation of driving behavior during the outbreak of the COVID-19 pandemic forms the motivation behind the current paper. Microscopic trip data captured by the OSEVEN insurance telematics and driving behavioral analytics platform (www.oseven.io), spanning from January to April 2020, are analyzed in order to assess driving behavior among two different countries (i.e. Greece and Saudi Arabia) with regards to different country-wise COVID-19 measures. The collected trip data are assessed based on the performance of drivers with regards to speed, the frequency of harsh braking, harsh acceleration, speeding events and mobile use, as well as trip characteristics (e.g. duration and distance) during the aforementioned data collection period.

By comparing the extent of detrimental consequences wrought by erroneous traffic behavior and COVID-19, there may be broader outputs in order to save more lives in the future. The value of reducing exposure as an effective intervention for road safety has been largely overlooked because road safety has been too narrowly focused on the road transport system itself. Furthermore, motorized private road transport reduction brings a host of several other benefits, such as less green-house gas emissions, noise or air pollution and greater opportunities for active transport. It is important to seize on the future opportunities in order to capture these benefits and re-think cities with safer road traffic and no accidents in the aftermath of the pandemic.

The paper is structured as follows: after the introduction to problem, a brief literature review on driving behavior and road safety in relation with COVID-19 or other pandemics on transportation is taking place. That section is followed by a description of the methodological approach and a description of the data collection and then the descriptive analysis of the data is presented. Finally,

conclusions on road safety effects of COVID-19 are drawn and a discussion on how policymakers and stakeholders should exploit the analysis takes place.

2 Literature Review

To date, the impact of COVID-19 on transportation can be evaluated through reports of individual academic institutes (e.g. Molloy, 2020) or data companies such as Google (Google LLC, 2020), Apple (2020) and TomTom(2020) which have published summary statistics of activities during the time of COVID-19. Although it is evident from these sources that traffic has been significantly reduced during the lockdown phase, the effect on driving behavior or road safety cannot be captured.

As a result the literature was searched in order to investigate if there is evidence for the relationship between driving behavior and past cases of recent pandemic outbreaks. Searching on popular scientific databases (i.e. Scopus and Google Scholar) with the Boolean terms {"COVID-19" or "Pandemic" and "driving behavior" or "driving behaviour" or "road safety"}, around 170 papers have been retrieved by 09/05/2020 and were screened on titles and abstracts. Unfortunately, title and abstract screening led to the conclusion that there is not yet a published study linking driving behavior or road safety with pandemics. The only relevant study would be the one by De Vos, (2020), where the potential effects of COVID-19 are theoretically discussed but no quantitate results or modelling takes place.

With regards to the previous 2009 H1N1 pandemic (Garten et al., 2009), the only evidence found with connection to the transportation domain, was the conclusion that transit stations played a significant role in spreading influenza (Cai et al., 2019) and how effective the closure of such stations along with the prevention of travelling (especially using the road infrastructure) in cases of pandemics can be (Xu et al., 2019).

Consequently, a gap in the literature exists, with regards to driver behavior characteristics in the time of a global pandemic.

3 Methodology

In order to quantify the effect of COVID-19 on driving behaviour and road safety of different countries, different sources of information need to be overviewed:

i. Driving behaviour data (both during COVID-19 and normal operations)
ii. Traffic data (ideally from national or regional traffic authorities) both during the COVID-19 pandemic but also during normal operations
iii. COVID-19 data with regards to cases and casualties as well as national countermeasures to prohibit dispersion of the virus

iv. Accident data

These different data sources could depict the impact of COVID-19 on how the drivers behave as well as on the enhancement or decrease of road safety. Data from normal operations could act as the baseline of driving behaviour and road safety, while the total number of cases and casualties due to COVID-19 would assist in comparing the different national strategies in prohibiting the virus.

4 Data collection

4.1 Driving behavior

For the purpose of the analysis, a 4-month timeframe from 29/12/2019 to 03/05/2020 and a database of trips from 67 countries, was created through the OSeven telematics application. The data collection system uses a smartphone application which tracks driving behavior with regards to harsh events (i.e. harsh acceleration and braking) and speeding using smart machine learning algorithms and reliable metrics. All the data within the OSeven platform follow clear privacy policy statements for the end users covering the type of data collected, the reason data is collected for, the time that data is stored and the procedures for data security based on encryption standards for data in transit and at rest. Furthermore, in compliance with the European Union General Data Protection Regulation (GDPR), all data that have been provided by OSeven Telematics are in an anonymized format.

The OSeven database consisted of 555,864completed routes, along with several driving performance measurements, which are described in Table 1.

Table 1: Driving indicators of the analyzed data with their corresponding description (*Source: OSeven*)

Indicator	Unit	Description
Total duration	sec	Total trip duration
Total distance	km	Total trip distance
Driving duration	sec	Total duration of driving, i.e. duration of stops has been excluded
Risky hours driving	km	Distance driven in risky hours (00:00 - 05:00)
Harsh accelerations	-	Number of harsh accelerations
Harsh braking	-	Number of harsh braking
Duration of speeding	sec	Total duration of speeding in a trip, i.e. driving over the "Speed Limit + Tolerance"
Average speeding	km/h	Average speed over the speed limit, i.e. driving over the "Speed Limit + Tolerance"
Average Total speed	km/h	Average speed during the total duration of the trip
Average Driving speed	km/h	Average speed during driving with stops been excluded from the duration of the trip
Time mobile usage	sec	Total duration of mobile usage

Table 2 depicts the frequency of the measured routes per country. Most trips

were completed in Greece and Saudi Arabia and therefore data from these three countries are going to be analyzed.

Table 2: Frequency of the measured trips per country (*Source: OSeven*)

Country	Total trips	Country	Total trips	Country	Total trips	Country	Total trips
Saudi Arabia	319,167	Portugal	546	Morocco	79	Slovakia	13
Greece	117,468	France	532	Malaysia	71	Mauritius	12
Cyprus	76,566	Argentina	495	Spain	62	Hungary	11
Brazil	13,959	Kuwait	357	Azerbaijan	61	Czech Republic	8
United States	7,256	Jordan	349	Qatar	60	N. Macedonia	8
United Kingdom	3,789	Bulgaria	345	Austria	58	Jersey	7
U. A. Emirates	1,465	Germany	318	Denmark	55	Andorra	6
Thailand	1,449	Indonesia	317	Romania	39	New Zealand	6
Ireland	1,384	Egypt	305	Serbia	38	Yemen	6
Bahrain	1,365	Lebanon	294	Colombia	35	Sweden	5
India	1,216	Pakistan	199	Poland	32	Paraguay	3
Netherlands	1,134	Turkey	168	Iran	26	Monaco	2
Australia	1,012	Japan	142	Albania	25	Israel	1
Russia	910	Switzerland	135	Ethiopia	25	Luxembourg	1
Canada	838	Syria	131	Peru	21	Palestine	1
Belgium	633	Italy	105	Sri Lanka	15	Singapore	1
Philippines	604	Mexico	105	Bangladesh	13		

Table 3 presents descriptive statistics (i.e. average, standard deviation, max, min,) with regards to the available parameters for the entire database in Greece and Saudi Arabia. In addition, Table 4 illustrates descriptive statistics for the parameters for the months after the appearance of COVID-19 in Greece and Saudi Arabia.

Table 3: Descriptive statistics for the available parameters for the entire database in Greece and Saudi Arabia

	Greece (117,468Trips)				Saudi Arabia (319,167Trips)			
	Mean	Standard deviation	Max	Min	Mean	Standard Deviation	Max	Min
Speeding	10.81	12.64	107.1	0	13.84	13.88	128.52	0
Average total speed (km/h)	34.47	19.35	168.38	1.97	45.2	21.72	216.11	1.92
Average driving speed (km/h)	42.24	18.01	184.67	7.01	52.69	20.31	216.11	1.92
Harsh Accelerations per km	0.13	0.29	5.5	0	0.11	0.22	4.57	0
Harsh Braking per km	0.2	0.33	8.2	0	0.22	0.31	5.35	0
Total Duration (sec)	983.99	1077.28	23880	61	1339.08	1629.02	31768	61
Driving Duration (sec)	770.97	941.28	21213	61	1110	1386.41	31438	61
Total Distance driven (km)	11.59	22.16	525.06	0.5	19.68	33.6	873.64	0.5
Risky Hours Driving (km)	0.36	3.84	353.98	0	67.31	22.8	100	10
Time of Mobile Use (sec)	37.05	150.18	6844	0	138.79	343.54	13472	0

Table 4: Descriptive statistics for the available parameters for the months of COVID-19 in Greece and Saudi Arabia

	Greece (117,468Trips)				Saudi Arabia (319,167Trips)			
	Mean	Standard deviation	Max	Min	Mean	Standard Deviation	Max	Min
Speeding	11.21	12.84	112.71	0	13.74	14.07	112.05	0
Average total speed (km/h)	36.21	20.01	156.43	3.12	46.30	22.13	175.64	3.75
Average driving speed (km/h)	43.81	18.59	183.08	7.89	53.84	20.71	181.08	8.18
Harsh Accelerations per km	0.13	0.29	5.19	0	0.11	0.23	4.57	0
Harsh Braking per km	0.2	0.34	5.5	0	0.23	0.33	4.16	0
Total Duration (sec)	963.94	1079.92	15194	61	1174.26	1431.17	31768	61
Driving Duration (sec)	769.42	950.72	14786	61	983	1253.2	31438	61
Total Distance driven (km)	11.99	22.28	426.94	0.5	17.95	31.5	837.23	0.5
Risky Hours Driving (km)	0.29	3.27	153.65	0	68.53	23.11	100	10
Time of Mobile Use (sec)	38.44	158.35	4326	0	144.28	352.55	9998	0

4.2 Traffic data

As getting data from traffic authorities usually requires time for data authorization and approval, it was decided to use the mobility data reports from Apple (Apple, 2020) as a proxy of the driving activities in the two aforementioned countries (i.e. Greece and Saudi Arabia).

The aggregated data collected from Apple show the mobility trends for major cities and several countries or regions. The information is generated by

counting the number of requests made to Apple for directions. The data sets are then compared to reflect a change in volume of people driving, walking or taking public transit around the world. 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. Table 5 depicts an example of dataset in routing requests both in Greece and Saudi Arabia.

Table 5: An example of dataset in routing requests in Greece and Saudi Arabia

	Greece		Saudi Arabia	
Date	Driving	Walking	Driving	Walking
26/2/2020	105.83	107.21	86.19	82.42
27/2/2020	107.2	113.48	114.36	109.9
28/2/2020	120.29	129.68	124.63	117.13
29/2/2020	115.89	139.7	89.83	92.4
1/3/2020	113.79	118.77	82.2	84.1
2/3/2020	139.75	91.9	82.18	82.57
3/3/2020	98.77	98.65	84.53	82.65

4.3 COVID-19 cases, casualties and countermeasures

4.3.1 Cases and Casualties

With regards to COVID-19 data, information was retrieved from the national ministries of health and were cross-checked with governmental press releases and popular webpages counting the spread of COVID-19 (e.g. Worldometer, 2020). Table 6 shows an example of dataset in total cases and deaths in Greece and Saudi Arabia.

The first case of COVID-19 was diagnosed in Greece on the 26th of February 2020 and in Saudi Arabia on the 5th of March. Table 6 illustrates the evolution of cases and casualties in both countries.

Table 6: Total cases and deaths in Greece and Saudi Arabia due to COVID-19

	Greece		Saudi Arabia	
Date	Total Cases	Total Deaths	Total Cases	Total Deaths
26/2/2020	1	0	-	-
27/2/2020	3	0	-	-
28/2/2020	4	0	-	-
29/2/2020	7	0	-	-
1/3/2020	7	0	-	-
2/3/2020	7	0	-	-
3/3/2020	7	0	-	-
4/3/2020	9	0	-	-
5/3/2020	31	0	5	0
6/3/2020	45	0	5	0
7/3/2020	66	0	7	0
8/3/2020	73	0	11	0

9/3/2020	84	0	15	0
10/3/2020	89	0	20	0
11/3/2020	99	0	45	0
12/3/2020	117	1	62	0
13/3/2020	190	1	86	0
14/3/2020	228	3	103	0
15/3/2020	331	4	118	0
16/3/2020	352	4	133	0
17/3/2020	387	5	171	0
18/3/2020	418	5	238	0
19/3/2020	464	6	274	0
20/3/2020	495	10	344	0
21/3/2020	530	13	392	0
22/3/2020	624	15	511	0
23/3/2020	695	17	562	1
24/3/2020	743	20	767	1
25/3/2020	821	22	900	2
26/3/2020	892	26	1,012	3
27/3/2020	966	28	1,104	3
28/3/2020	1,061	32	1,203	4
29/3/2020	1,156	38	1,299	8
30/3/2020	1,212	43	1,453	8
31/3/2020	1,314	49	1,563	10
1/4/2020	1,415	50	1,720	16
2/4/2020	1,544	53	1,885	21
3/4/2020	1,613	59	2,039	25
4/4/2020	1,673	68	2,179	29
5/4/2020	1,735	73	2,385	34
6/4/2020	1,755	79	2,523	38
7/4/2020	1,832	81	2,795	41
8/4/2020	1,884	83	2,932	41
9/4/2020	1,955	86	3,287	44
10/4/2020	2,011	90	3,651	47
11/4/2020	2,081	93	4,033	52
12/4/2020	2,114	98	4,462	59
13/4/2020	2,145	99	4,934	65
14/4/2020	2,170	101	5,369	73
15/4/2020	2,192	102	5,862	79
16/4/2020	2,207	105	6,380	86
17/4/2020	2,224	108	7,142	87
18/4/2020	2,235	110	8,274	92
19/4/2020	2,238	113	9,362	97
20/4/2020	2,245	116	10,484	103
21/4/2020	2,401	121	11,631	109
22/4/2020	2,408	121	12,772	114
23/4/2020	2,463	125	13,930	121
24/4/2020	2,490	130	15,102	127
25/4/2020	2,506	130	16,299	136
26/4/2020	2,517	134	17,522	139
27/4/2020	2,534	136	18,811	144
28/4/2020	2,566	138	20,077	152
29/4/2020	2,576	139	21,402	157
30/4/2020	2,591	140	22,753	162
1/5/2020	2,612	140	24,097	169
2/5/2020	2,620	143	25,459	176
3/5/2020	2,626	144	27,011	184

4.3.2 Response measures

Greece

Table 7 summarizes the timeline of Covid-19 response measures that have been announced by the Greek Government.

Table 7: Timeline of Covid-19 response measures in Greece

Response measures	Date
Appearance of COVID-19	26/2/2020
Closure of educational institutions	10/3/2020
Closure of shopping centers and cafes	13/3/2020
Suspension of religious services	16/3/2020
Lockdown of non-essential movements	23/3/2020

Saudi Arabia

Table 8 summarizes the timeline of Covid-19 response measures that have been announced by the Saudi Arabian Government.

Table 8: Timeline of Covid-19 response measures in Saudi Arabia

Response measures	Date
Appearance of COVID-19	5/3/2020
Closure of educational institutions	9/3/2020
Closure of shopping centers and cafes	13/3/2020
Suspension of religious services	20/3/2020
Lockdown of non-essential movements	23/3/2020

4.3.3 Overview of the evolution of cases and casualties

Figures 1 and 2 show the evolution of cases and casualties from COVID-19 along with the respective countermeasures from the local governments in Greece and Saudi Arabia.

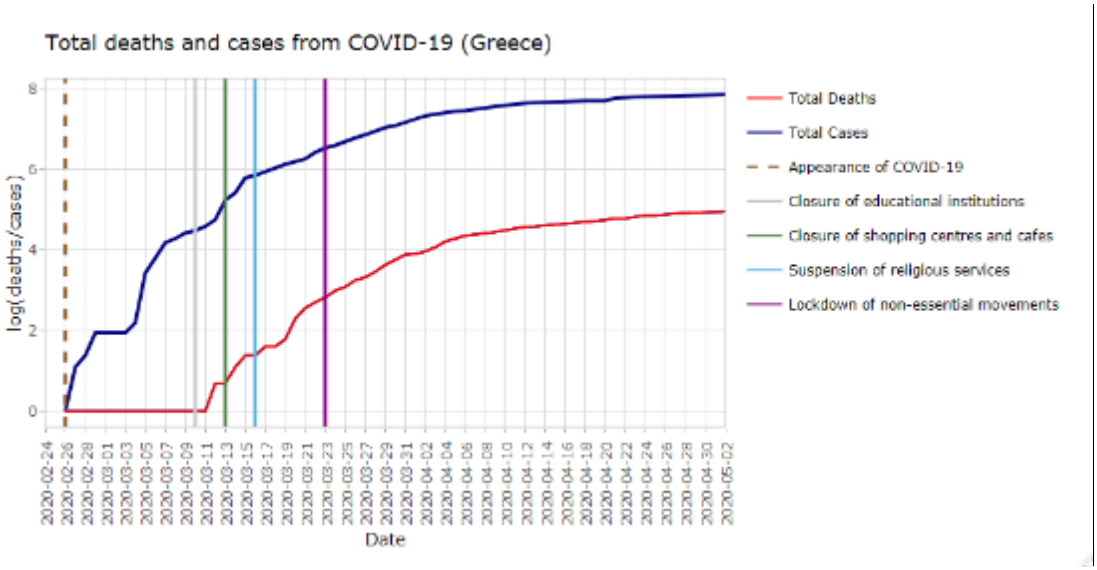

Figure 1: Evolution of total deaths and cases in Greece

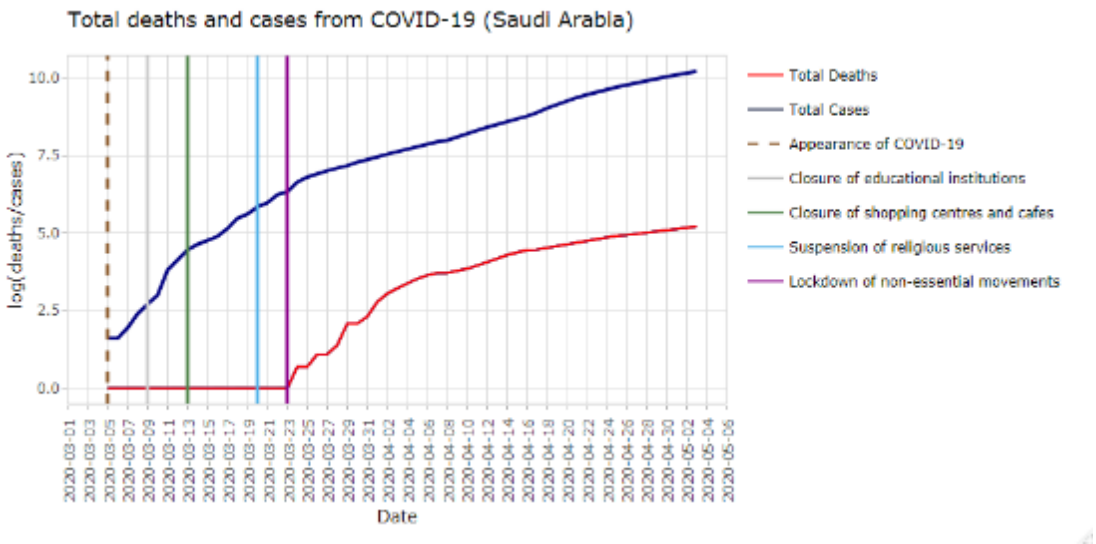

Figure 2: Evolution of total deaths and cases in Saudi Arabia

4.4 Road Accidents data

With regards to road accidents, only Greek data on deaths, severe and slight injuries accidents were available until the end of March 2020. Therefore, a comparison between countries cannot be drawn but for completion the data are displayed in section 5 to draw conclusions along the driving behavior data of Greek drivers.

5 Cross-country exploratory analysis of driving behaviour and road safety

As mentioned before, the purpose of this paper is to compare and assess driving behavior in two countries (i.e. Greece and Saudi Arabia) with regards to traffic as well as driving behavior and trip characteristics in the time of

coronavirus-induced lockdown. This section will present the results of the exploratory analysis.

5.1 Driving and Walking volumes

Greece

Figure 3 depicts the volume of driving and walking sessions of Apple users in Greece from January 2020 and until early May2020.

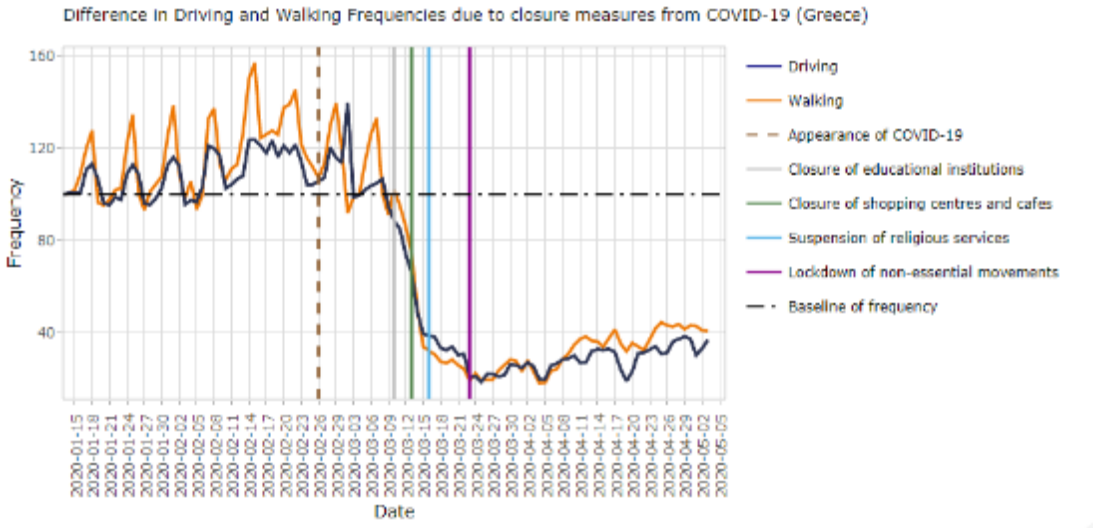

Figure 3: Change in routing requests since 13 January 2020 in Greece

(*Source: Apple*)

It is evident that there is a significant reduction in the volume of people driving and walking during the COVID-19 spreading in Greece. 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 is observed. Traffic volumes have dropped roughly 10% since the first week of March and up to 75% since the first week of April compared to the baseline (i.e. the average figures for the months before the COVID-19 pandemic).

Furthermore, Table 9 depicts the change that occurred in traffic volume in Greece between March and April compared to February. Specifically, a 41.85% reduction of people driving and a 41.39% reduction of people walking was identified in March compared to February. At the same time, a significant 73.96% reduction of people driving and a remarkable 72.31% reduction of people walking was identified in April compared to February.

Table 9: Change in traffic volume in Greece (*Source: Apple*)

	Change compared to February	
	March	**April**
Driving	-41.85%	-73.96%
Walking	-41.39%	-72.31%

To further clarify the impact of COVID-19 countermeasures on driving and walking patterns, Figure 4 depicts driving and walking patterns in comparison with the number of COVID-19 casualties and the countermeasures taken from the Greek government. It can be observed that a crucial drop in walking and driving began with the shutdown of schools and all educational institutes and continued until the decision for lockdown on the 23rd of March.

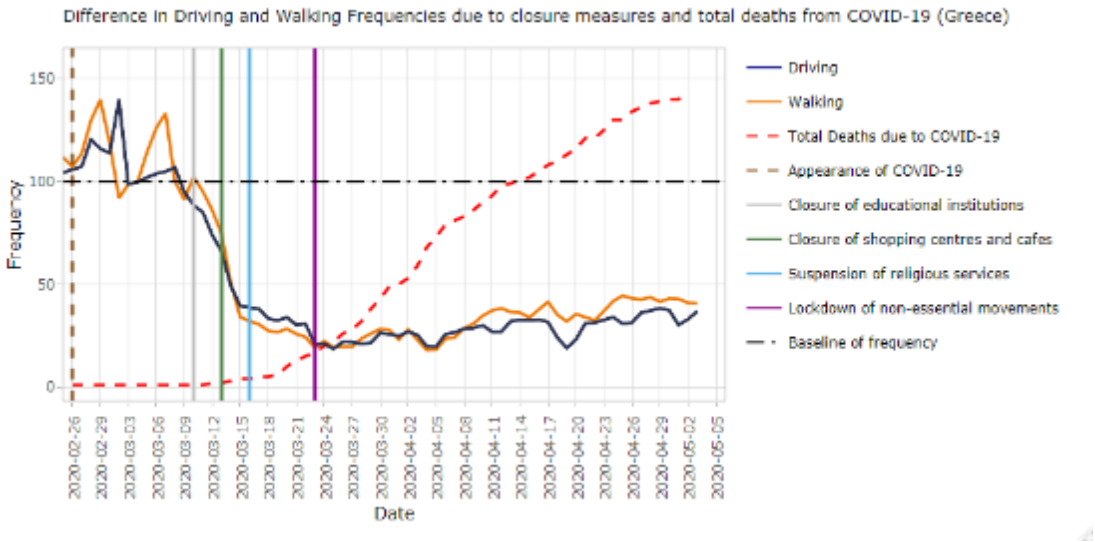

Figure 4: Change in routing requests with corresponding deaths since 26 February 2020 in Greece

Saudi Arabia

With regards to Saudi Arabia, similarly with Greece, both driving and walking were significantly less frequent in the time of COVID-19. Nevertheless, as depicted in Figure 5, the reduction was smaller than in Greece with a 56% and 47% reduction for driving and walking respectively. Traffic volumes have dropped up to 20% since the first week of March and up to 50% since the first week of April.

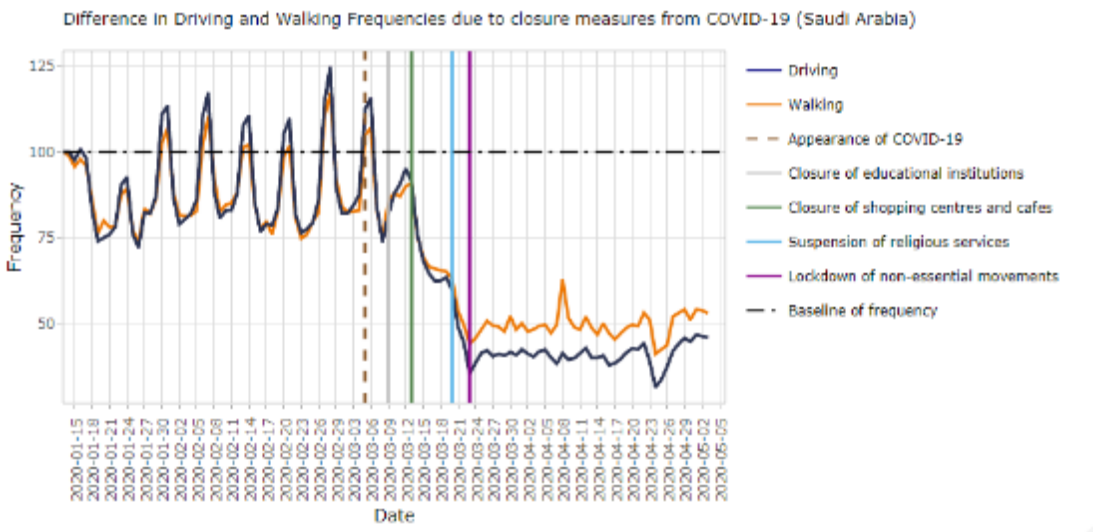

Figure 5: Change in routing requests since 13 January 2020 in Saudi Arabia *(Source: Apple)*

Table 10 depicts the change that occurred in traffic volume in Saudi Arabia between March and April compared to February. Specifically, a 25.86% reduction of people driving and a 21.74% reduction of people walking was identified in March compared to February. At the same time, a significant 54.78% reduction of people driving and a remarkable 44.22% reduction of people walking was identified in April compared to February.

Table 10: Change in traffic volume in Saudi Arabia (*Source: Apple*)

	Change compared to February	
	March	**April**
Driving	-25.86%	-54.78%
Walking	-21.74%	-44.22%

Figure 6 illustrates driving and walking patterns in comparison with the number of COVID-19 casualties and the countermeasures taken from the Saudi Arabian government. It can be observed that a crucial drop in walking and driving began with the shutdown of schools and all educational institutes and continued until the decision for lockdown on the 23th of March.

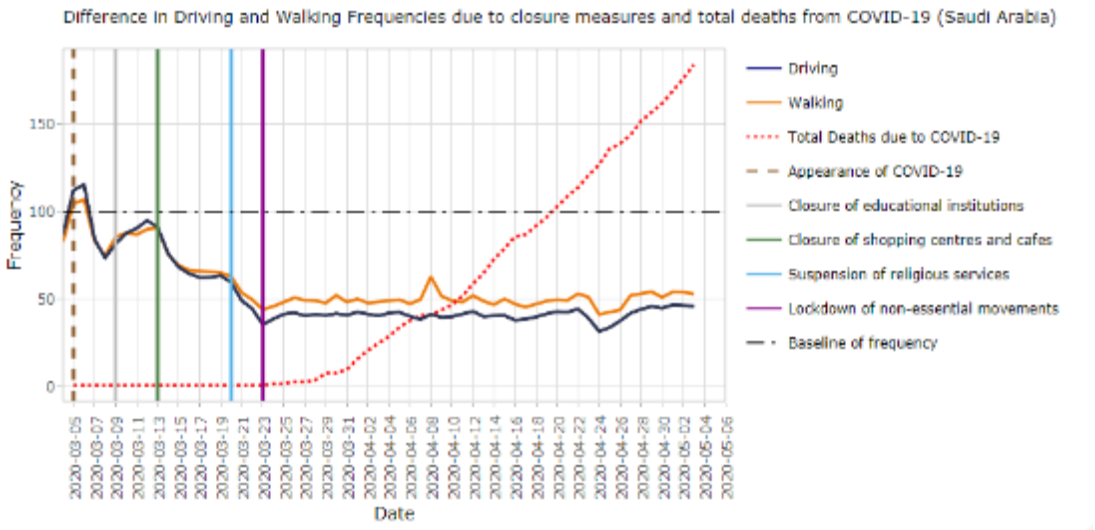

Figure 6: Change in routing requests with corresponding deaths since 5 March 2020 in Saudi Arabia (*Source: Apple*)

5.2 Speed and Speeding

Before beginning to illustrate the results on driving behavior and trips characteristics, it should be mentioned that all the figures in Sections 5.2, 5.3 and 5.4, illustrate the mean metrics of the indicators mentioned in Table1 per week. Therefore the horizontal axis in these figures denote the beginning of each week, i.e. the measurement on the 26th of April denotes the mean indicator for all trip data during the week between the 26th of April and the 4th of May.

Speeding

Figure 7 indicates that with fewer vehicles on city streets, slightly more drivers are blowing the speed limit. Although with less traffic, drivers are getting to their destinations faster, there was also a slight increase in the average speed over the speed limit. First reported in March a 2% spike in average speeding compared to a normal period in February. Moreover, a 7% increase in average speeding was found in April compared to February. It is worth mentioning that a significant increase in average speeding was pointed out, before the lockdown had been announced.

Similarly, in Saudi Arabia as depicted in Figure 8, a 4% increase in average speeding was found in March compared to February, while a 5% increase in average speeding was found in April compared to a normal period in February.

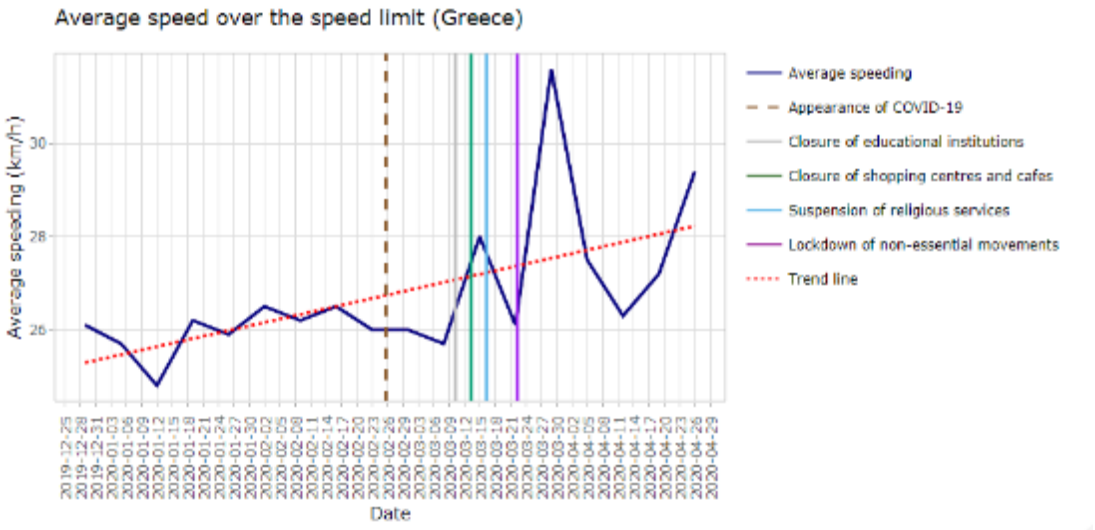

Figure 7: Average speed over the speed limit per week in Greece

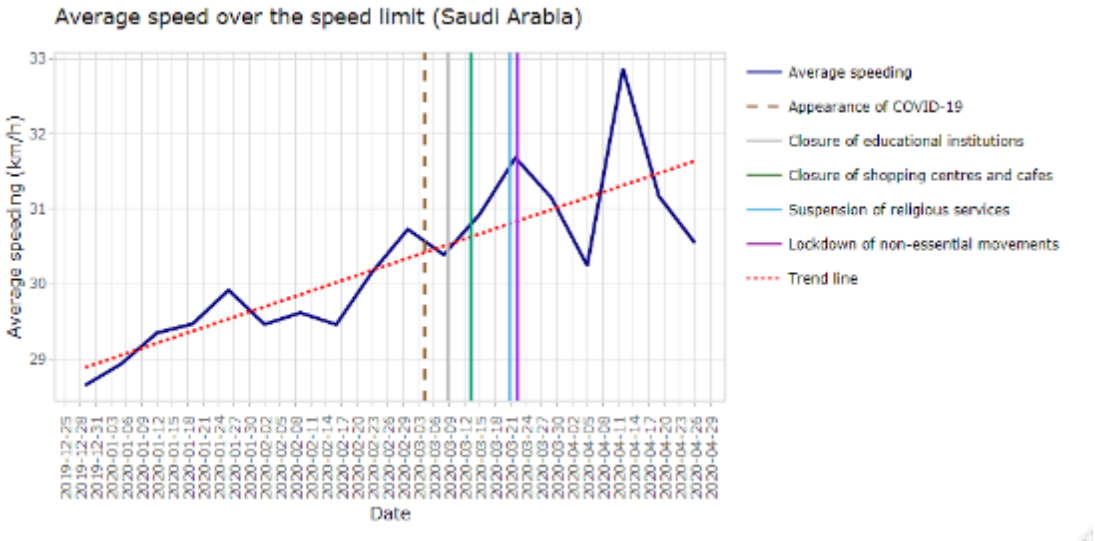

Figure 8: Average speed over the speed limit per week in Saudi Arabia

Average Total Speed

With regards to the total average speed, a 6% increase was found in March compared to February, while an 11% increase in average speed was observed in April compared to the normal period of February, as shown in Figure 9. With regards to the average speed in Saudi Arabia, a 5% increase in average speed was found in March and an 8% increase was determined in April compared to a normal period in February, as shown in Figure 10.

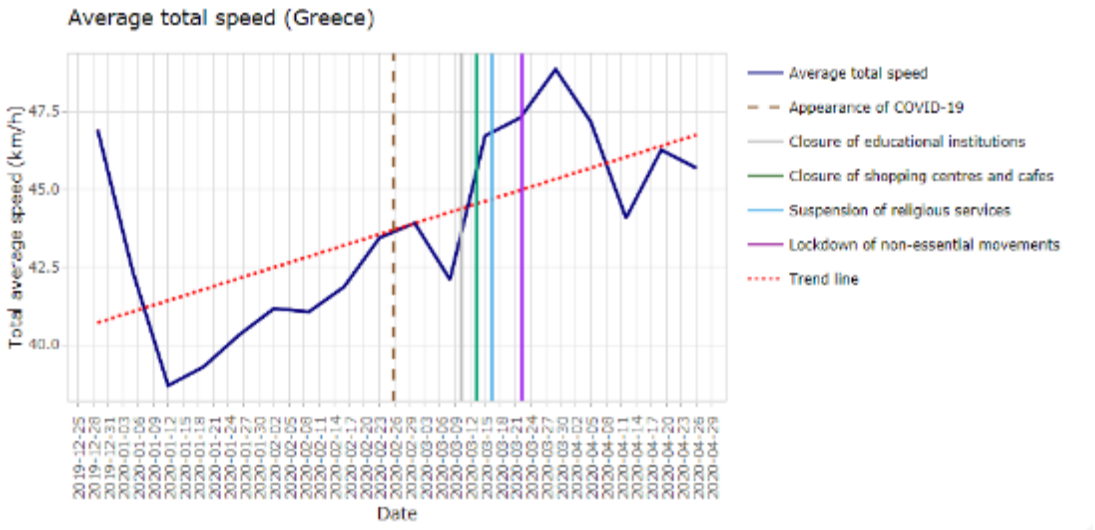

Figure 9: Total average speed per week in Greece

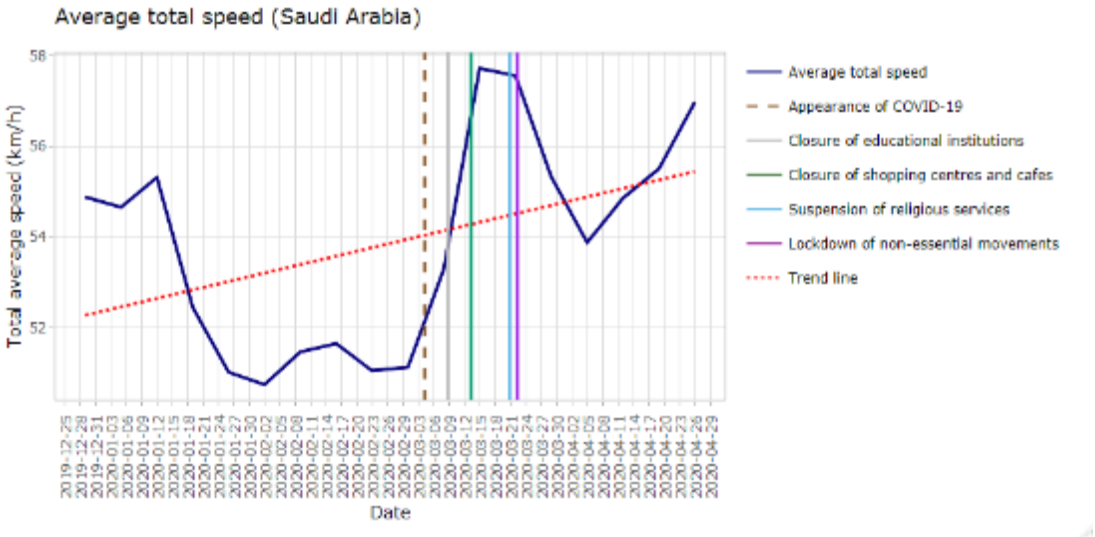

Figure 10: Average total speed per week in Saudi Arabia

Average Driving Speed

Figure 11 shows evidence of driving average speed, especially, after the first appearance of COVID-19. A 4% increase in driving average speed was determined in March as well as a 6% increase in driving average speed was found in April compared to February.

In Saudia Arabia the corresponding increase in driving speed ranged from 4% in March to 7% in April compared to February. Nevertheless, it can be observed that speeds were higher in Saudi Arabia than Greece during the lockdown phases, as shown in Figure 12.

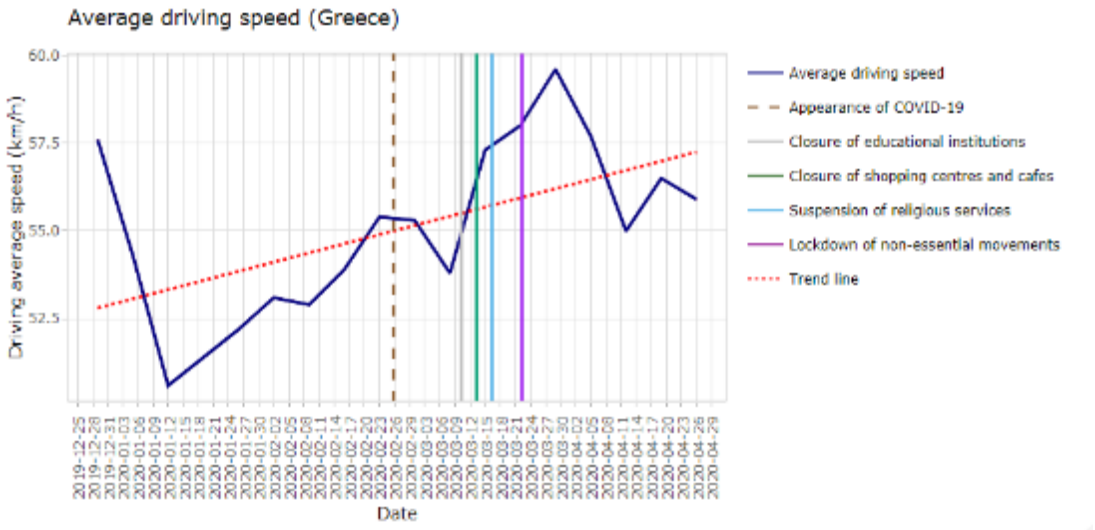

Figure 11: Average driving speed per week in Greece

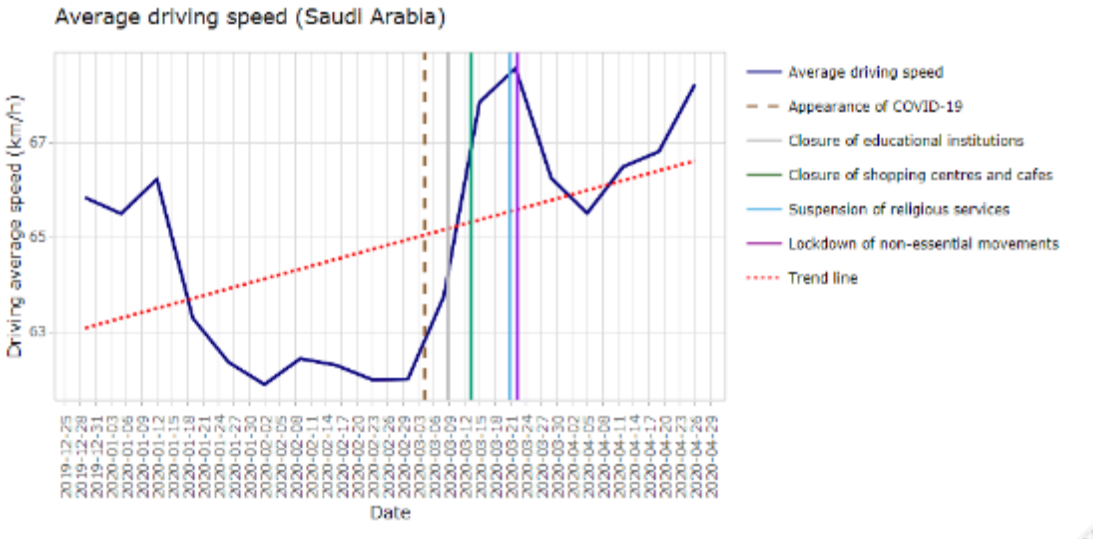

Figure 12: Average driving speed per week in Saudi Arabia

5.3 Harsh Events

Harsh Acceleration Events

With regards to harsh accelerations, although in March and during the first phase of the lockdown a 6% reduction was observed, in April harsh accelerations were increased by 5% compared to February, as shown in Figure 13.

Drivers were found to accelerate harshly in Saudi Arabia during the months of COVID-19. Specifically, in March 3% more harsh accelerations per km were

observed, while in April this percentage has risen to 11%, as depicted in Figure 14.

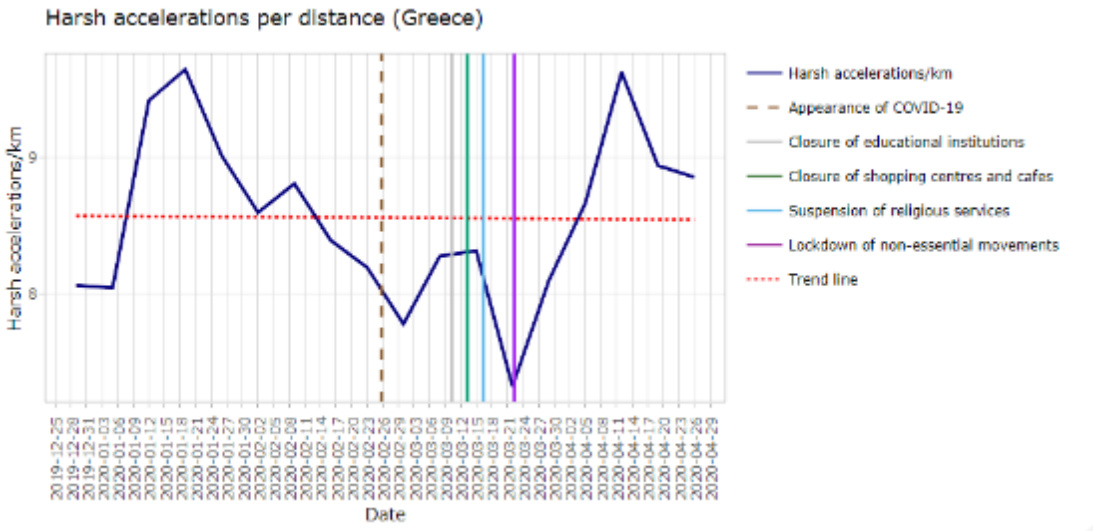

Figure 13: Harsh accelerations per distance per week in Greece

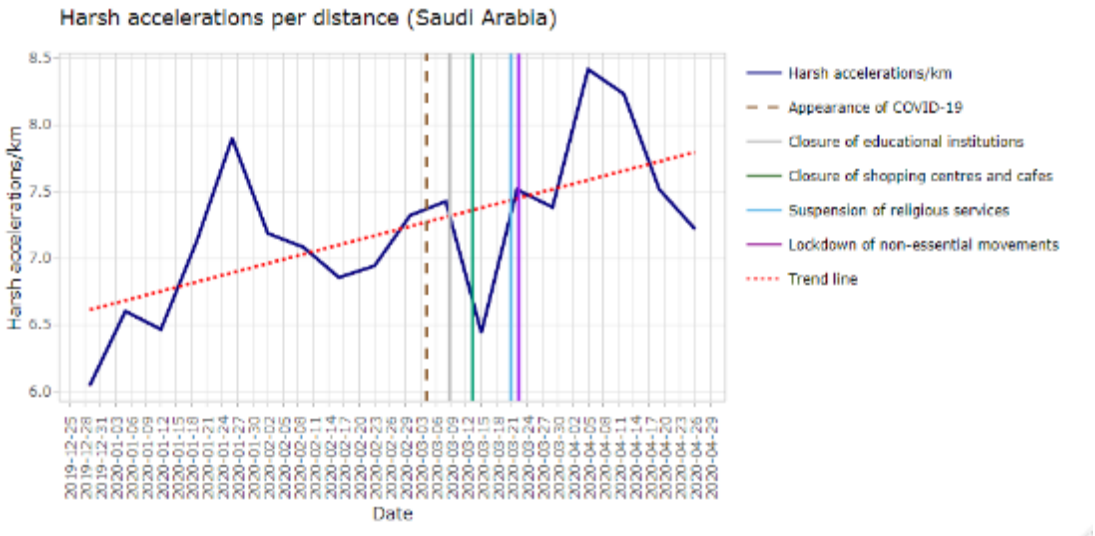

Figure 14: Harsh accelerations per distance per week in Saudi Arabia

Harsh Braking Events

With regards to harsh braking as illustrated in Figure 15, data showed a minor decrease of 3% during March but a significant 12% increase in April. This is probably due to the fact that with emptier roads drivers tend to increase their speed more and braked suddenly when an obstacle or pedestrian was observed.

The increase in harsh braking events is more obvious in Figure 16 and the data for Saudi Arabia. It can be observed that harsh braking is having an upward trend especially after the closure of religious services and the initiation of the

lockdown. Specifically, only a 0.31% increase in harsh braking per distance was found in March compared to February, while a significant 10% increase in average harsh braking per distance was found in April.

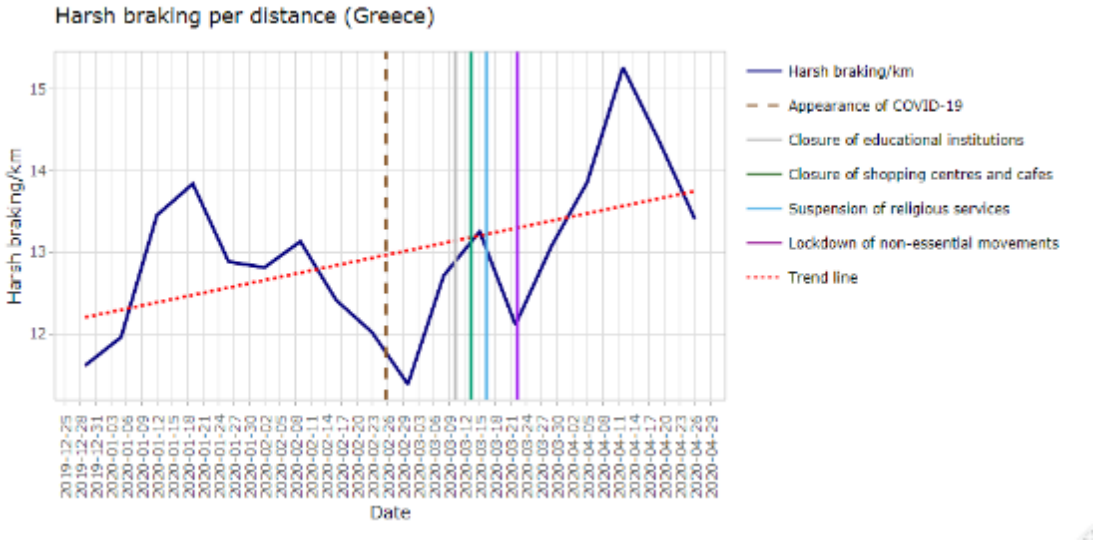

Figure 15: Harsh braking per distance per week in Greece

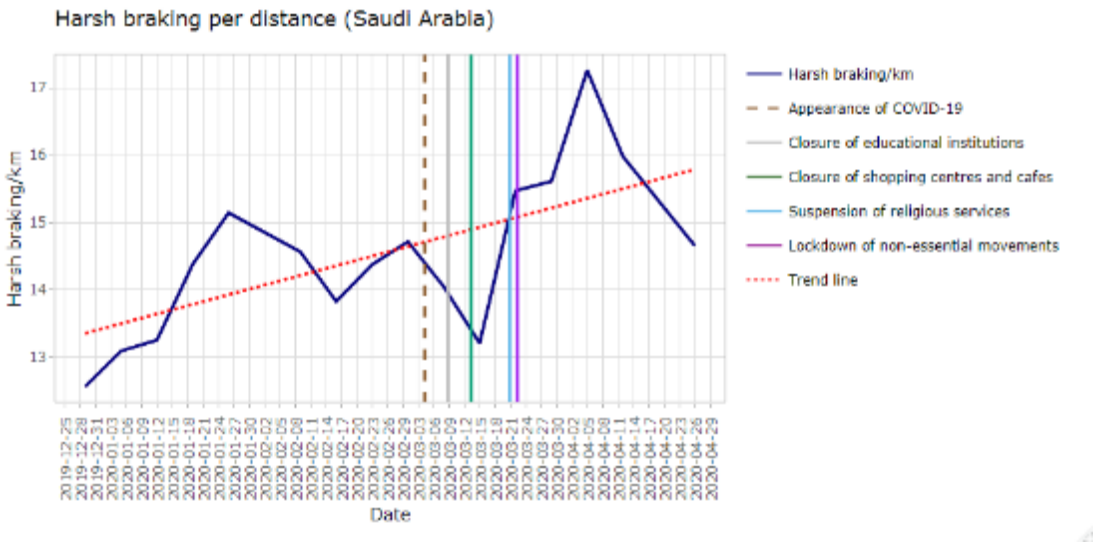

Figure 16: Harsh braking per distance per week in Saudi Arabia

5.4 Trip Characteristics

Total Duration

As shown in Figures 17 and 18, both in Greece and Saudi Arabia driving trips were significantly reduced due to the lockdown. A 29% reduction in total duration was observed for Greece in March and a 65% reduction in April. Similarly, in Saudi Arabia 30% shorter trips were made in March and 73% shorter trips were observed during April.

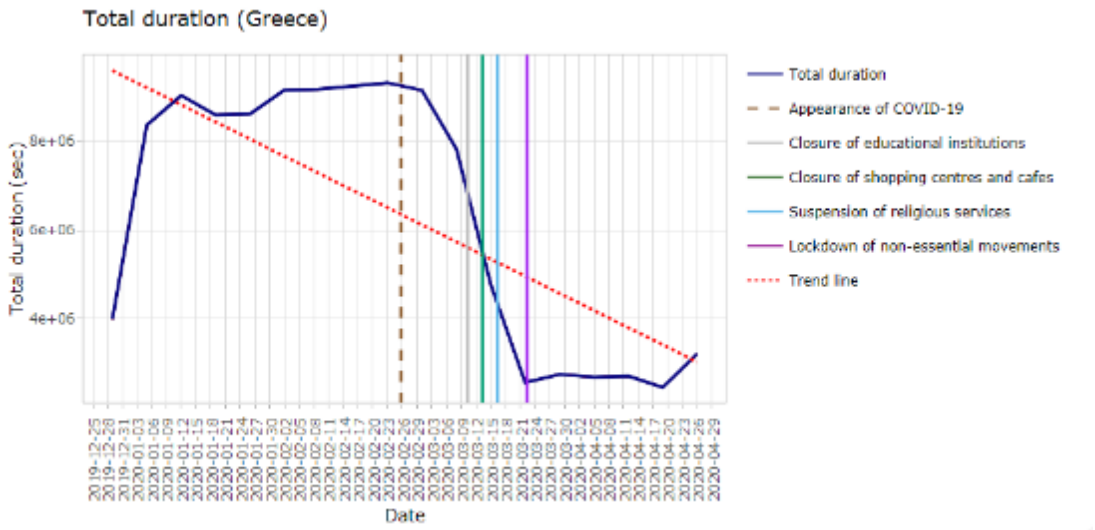

Figure 17: Total duration per week in Greece

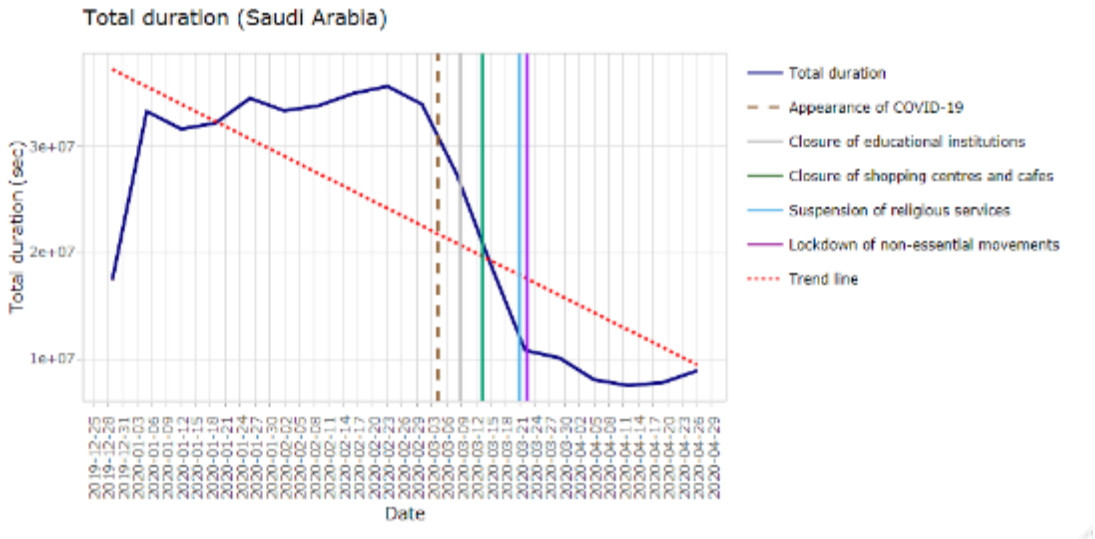

Figure 18: Total duration per week in Saudi Arabia

Driving Duration

In accordance with the driving lengths, Figures 19 and 20 illustrate a significant reduction also with regards to driving duration especially, after the first appearance of the pandemic.

In Greece a 31% decrease in driving duration was found during March and a significant 74% was illustrated during April. The reduction was greater in Saudi Arabia, with 32% in March and 75% shorter trips during April.

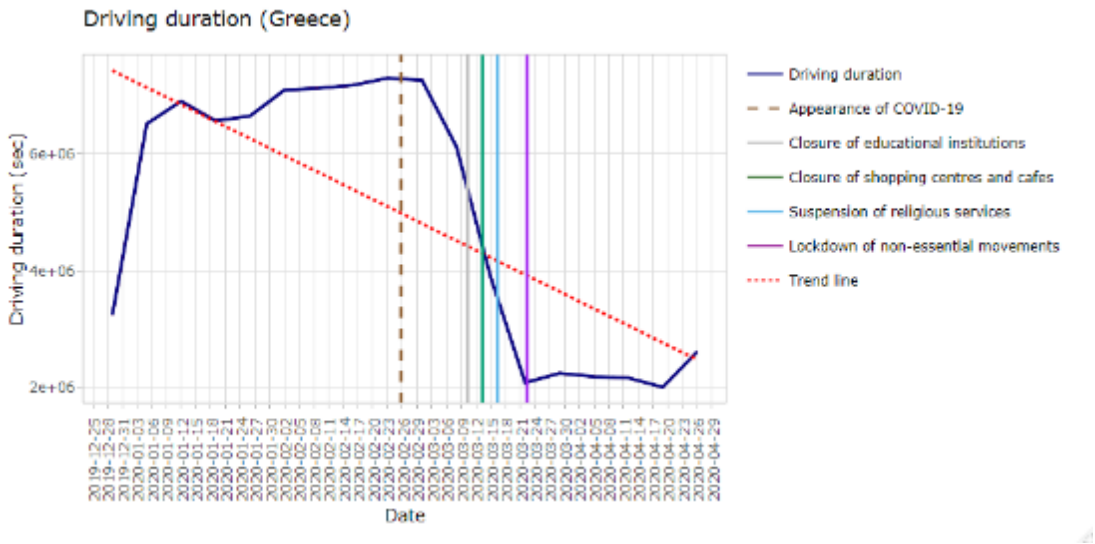

Figure 19: Driving duration per week in Greece

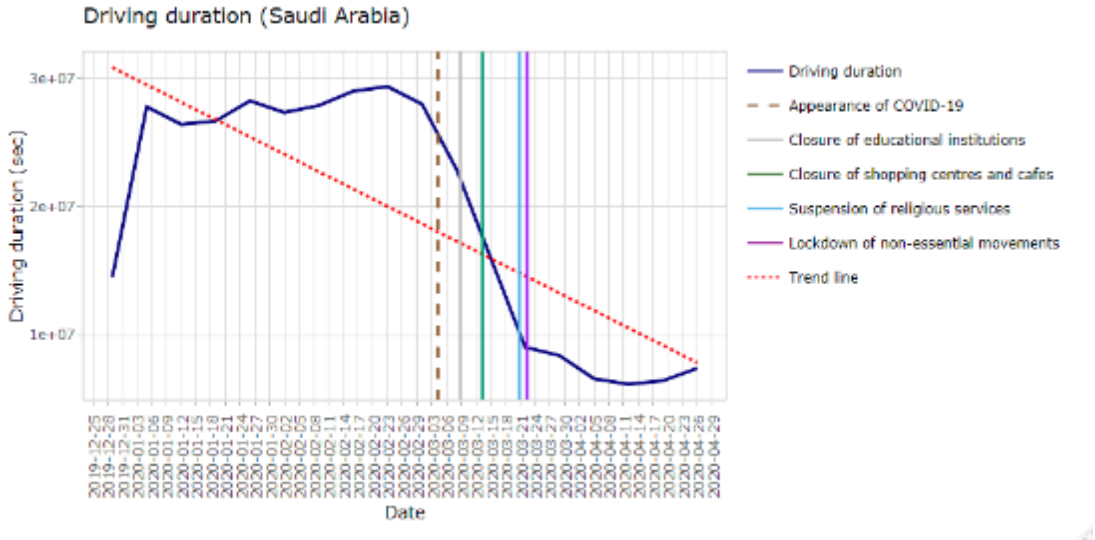

Figure 20: Driving duration per week in Saudi Arabia

Distance Driven

Work and travel restrictions mean that overall, it is likely that less journeys are being made. For road safety, this may be an upside: less journeys should

theoretically mean less crashes. There is evidence that since the Covid-19 pandemic, there has been a reduction in distance driven, as shown in Figure 21. Greece started to increase weekly mileage, reaching a 29% decrease in total distance monitored in March, compared to February. Interestingly, total driving distance per week had already dropped by around 65% in April after the lockdown had even been announced.

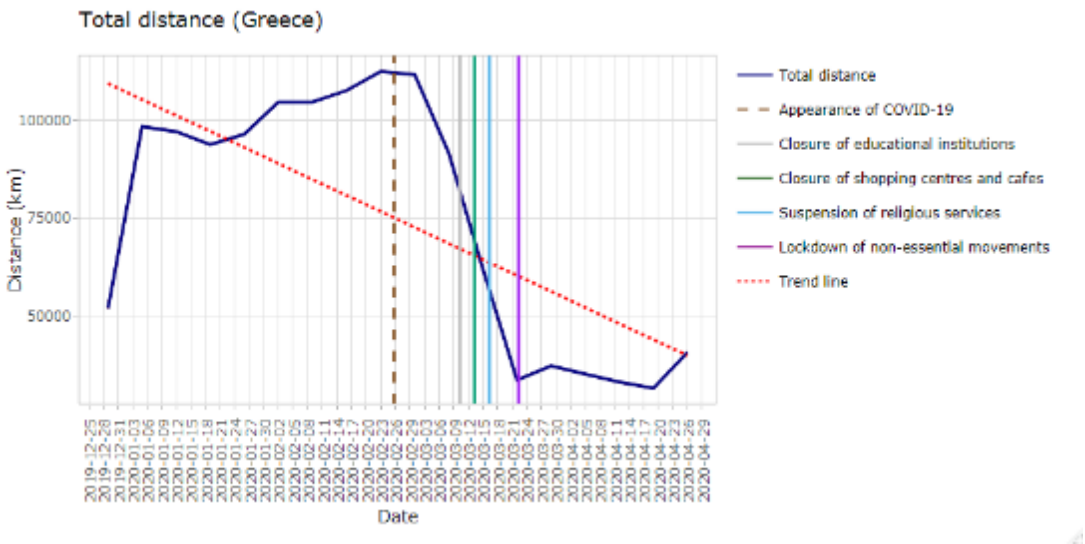

Figure 21: Total driving distance per week in Greece

With regards to distance driven in Saudi Arabia, a 30% decrease in total driving distance was determined in March, as well as a significant 73% reduction in total driving distance was determined in April compared to a normal period in February, as shown in Figure 22.

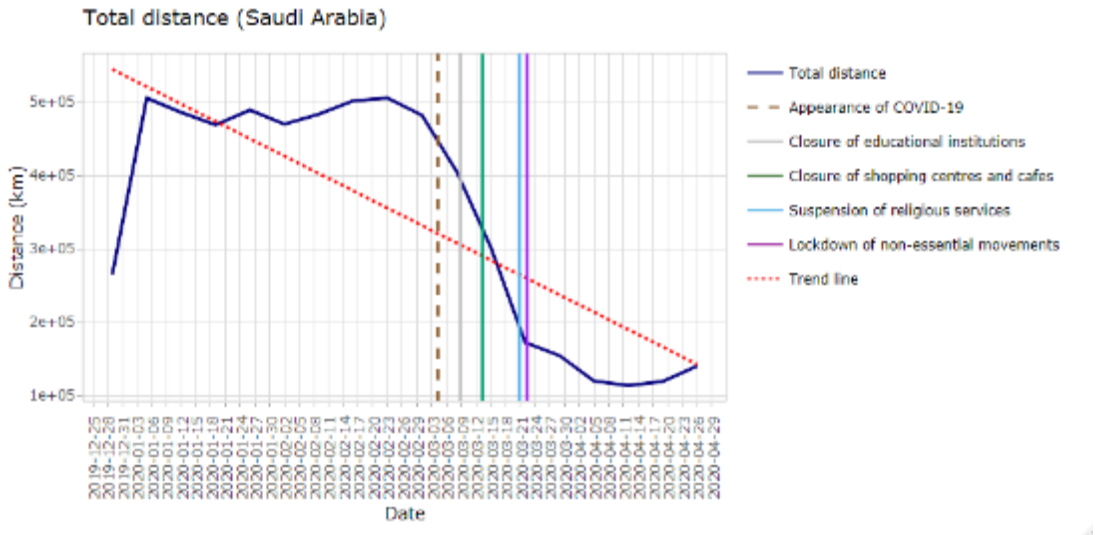

Figure 22: Total driving distance per week in Saudi Arabia

Risky Hours

Figure 23 shows a reduction in distance driven in risky hours, from 00:00am to 05:00am, especially after the total lockdown throughout Greece. In particular, a 45% reduction in risky hours driving was found in March compared to February, while a significant 74% decrease in risky hours driving was determined in April compared to a normal period in February.

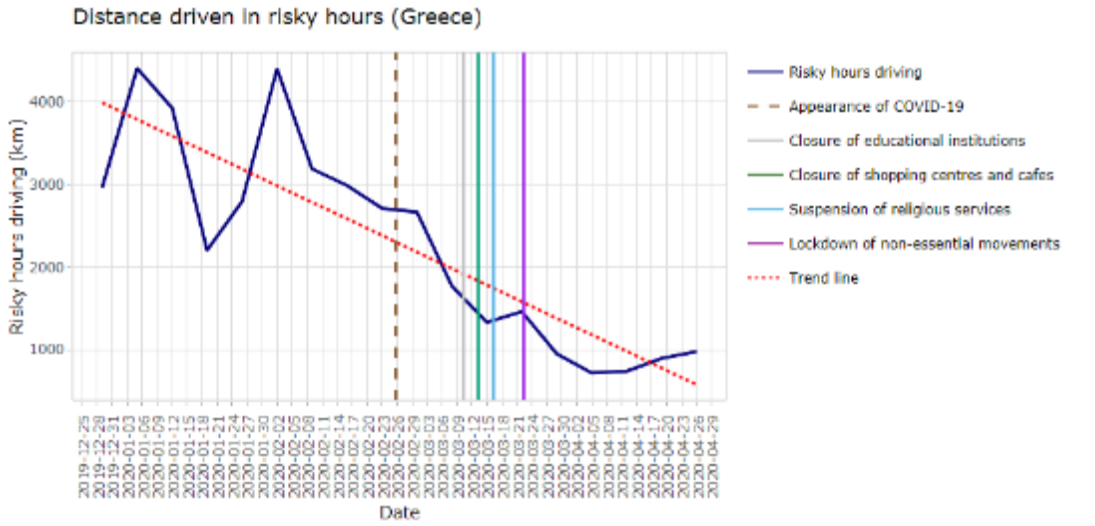

Figure 23: Distance driven in risky hours (00:00-05:00) per week in Greece

A significant reduction in distance driven in risky hours, was observed in Saudi Arabia. In particular, a 33% reduction in risky hours driving was found in March compared to February, and an extreme 81% decrease in risky hours driving was determined in April compared to a normal period in February, as shown in Figure 24.

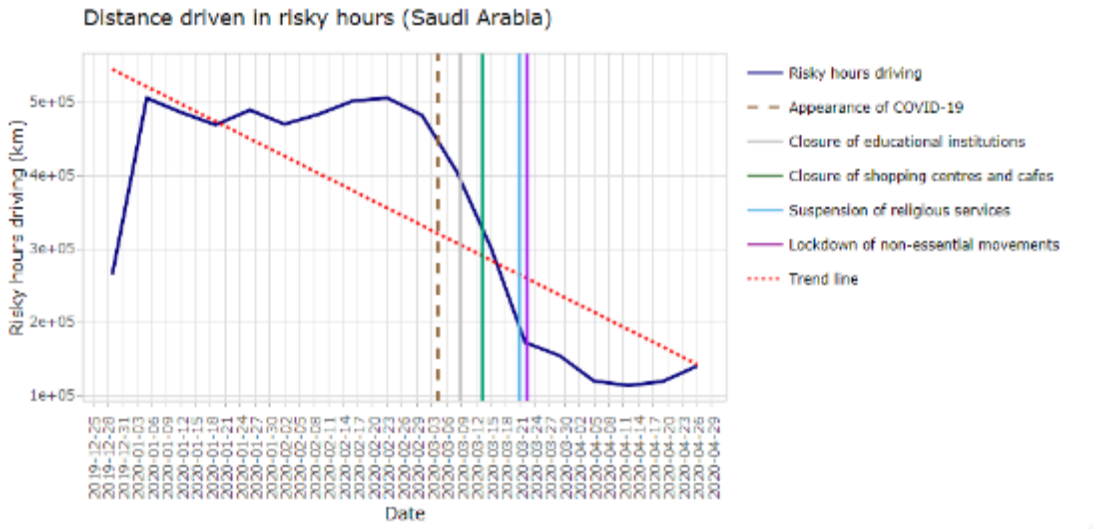

Figure 24: Distance driven in risky hours (00:00-05:00) per week in Saudi

Mobile Phone Usage

With regards to mobile phone use, Figures 25 and 26 illustrate a general decrease in mobile phone use with significant differences when comparing data from March and April (i.e. COVID-19 months) with data from February (i.e. normal operations). In more detail, a 32% decrease in duration of mobile phone usage was found in March and a 60% decrease in duration of mobile phone usage was found in April for Greece and a 24-65% reduction was observed in Saudi Arabia.

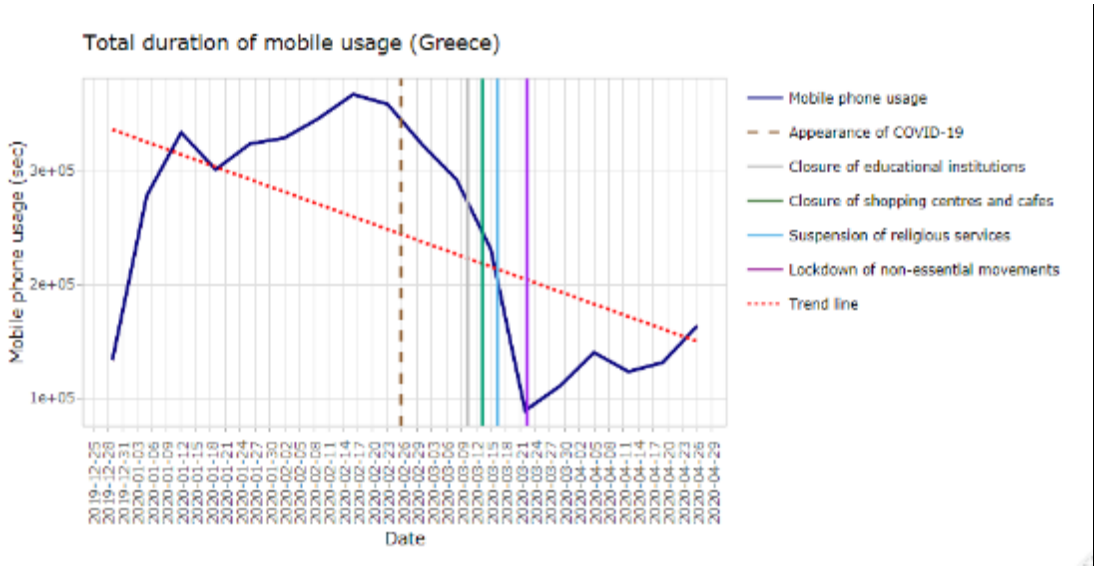

Figure 25: Total duration of mobile phone usage per week in Greece

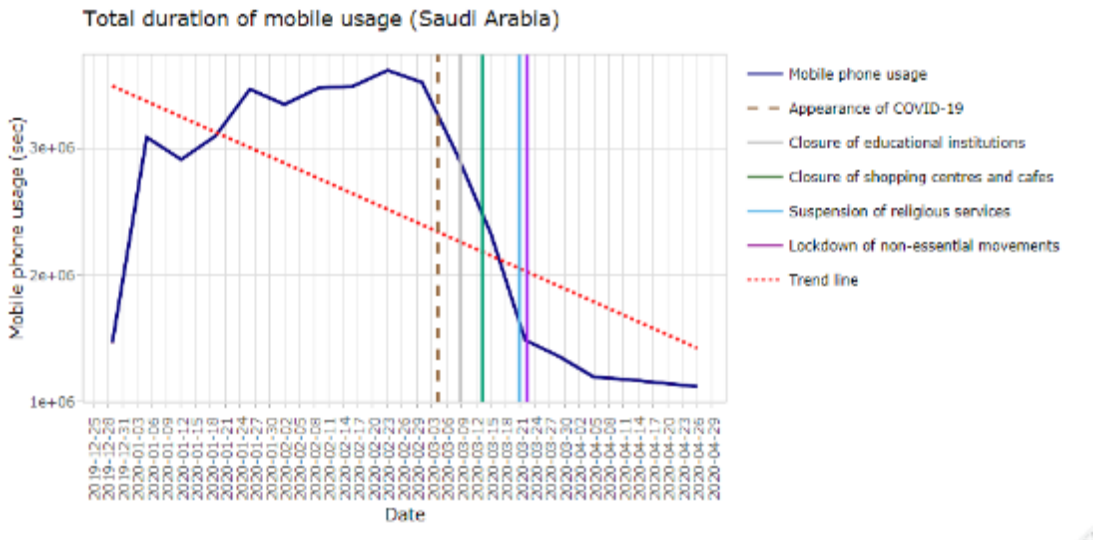

Figure 26: Total duration of mobile phone usage per week in Saudi Arabia

5.5 Summary

Table 11 summarizes the changes in driving behavior and trip characteristics during the months of COVID-19, when compared with January and February 2020, when the coronavirus did not have an impact on everyday life.

Table 11: Changes in driving behavior and trip characteristics during the months of COVID-19 compared to January and February 2020

Greece

Measurement	Change compared to January			Change compared to February	
	February	March	April	March	April
Average speeding	2%	4%	9%	2%	7%
Average total speed	2%	9%	13%	6%	11%
Average driving speed	2%	6%	8%	4%	6%
Harsh accelerations/km	-5%	-10%	0.25%	-6%	5%
Harsh braking /km	-1%	-4%	10%	-3%	12%
Total duration	2%	-32%	-68%	-33%	-68%
Driving duration	2%	-30%	-66%	-31%	-74%
Distance	4%	-26%	-64%	-29%	-65%
Risky hours driving	-8%	-50%	-76%	-45%	-74%
Time mobile use	8%	6%	31%	-32%	-60%

Saudi Arabia

Average speeding	1%	5%	6%	4%	5%
Average total speed	-4%	1%	4%	5%	8%
Average driving speed	-3%	0.35%	3%	4%	7%
Harsh accelerations/km	1%	4%	12%	3%	11%
Harsh braking /km	3%	4%	14%	0.31%	10%
Total duration	-2%	-34%	-76%	-33%	-75%
Driving duration	-2%	-34%	-76%	-32%	-75%
Distance	-5%	-33%	-75%	-30%	-73%
Risky hours driving	-17%	-44%	-84%	-33%	-81%
Time mobile use	6%	-20%	-62%	-24%	-65%

From Table 11, it is evident that the most significant effects of COVID-19 in Greece were the increased speed as well as the increase on the frequency of harsh braking events/km. Trips were significantly shorter both in distance and

duration, which is obviously due to the prohibitions imposed by the Greek government and essentially less trips were done during risky hours. Finally, the reduced mobile use by Greek drivers is evidence of enhanced road safety during the time of the COVID-19 response measures.

With regards to Saudi Arabia, although speed did not change significantly, both harsh accelerations and harsh braking were increased by roughly 10%. This is probably due to the fact that roads were emptier and drivers could accelerate more while obstacles or pedestrians crossing the empty road infrastructure lead to a combination of harsh acceleration and braking. Trips in Saudi Arabia, were significantly shorter (in distance and time) similarly with Greece, but driving during risky hours had a major reduction of 33-81%. Mobile phone usage especially during April, was decreased similarly to Greece, which denotes safe driving behavior.

5.6 Accidents in Greece during COVID-19

Table 12 illustrates the difference in accident rates between February and March 2020. It is shown that a significant 41% reduction in total number of road accidents was observed during March 2020, when the majority of response measures regarding COVID-19 took place. Furthermore, during March 2020, the total number of deaths was decreased by 41%, severe injuries dropped by 8%, while slight injuries accidents were reduced by 42%.

Table 12: Road safety in Greece during February and March 2020
(*Source: Greek Traffic Police)*

	February 2020	March 2020	Change
Deaths	34	20	-41%
Severe injured	24	22	-8%
Slightly injured	633	365	-42%
Total number of road accidents	691	407	-41%

6 Conclusions on road safety and policy recommendations

COVID-19 "invaded" everyday life abruptly, which induced a significant change in everyday life commuting and travel behavior. The measures taken by local governments to restrict the spread of the coronavirus were immediate and strict, but eventually seem to have positive effects on diminishing the exponential dispersion of COVID-19 and ensure public health. For example as of May 4th 2020, Greece has started to loosen the lockdown status gradually.

During the two months that COVID-19 was spreading in Greece and Saudi Arabia, it effected significantly aspects of road safety and driving behavior. Trips

were undoubtedly shorter, but speeds were slightly increased. Drivers were more prone to harsh events during the lockdown phase, and especially harsh braking. This was probably an indirect effect of the increase in driving speed. It was observed that drivers reduced the number of trips taken between midnight and 5:00, and use their mobile phones less while driving, thus reducing the risk of accidents.

The increase of speeds, speeding rates and the frequency of harsh events denotes a deterioration of safety levels among drivers during the COVID-19 lockdown. Although this deterioration is not illustrated in accident numbers in Greece, such behaviors could become the target objective of policy interventions on the "epidemic"-like phenomenon of traffic accidents(Hazen and Ehiri, 2006; Sharma, 2008). Whereas road infrastructure safety improvement and safer vehicles penetration require several years before witnessing major results, traffic behavior can certainly be controlled and improved much faster, if social acceptance is raised and political will is strong and sincere. Managing efficiently (by police enforcement and massive campaigns) the five major traffic killers (speeding, mobile-phone-use, drink-and-drive, seat belt and helmet non-use) can be proved highly beneficial with a great number of lives saved even at short term.

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, efficient traffic safety measures should be taken as soon as possible, so that traffic accident rates are not increased again.

Focus should specifically be given by policymakers to the major traffic killers (speeding being the most important) and to measures bringing results quickly. For instance, these measures could concern:

- New speed limits applying to all roads horizontally (with important benefits also for the environment):
    - 30 km/h in urban areas (50 km/h in major urban axes), similar to the practices applies in major European cities (ETSC, 2020; ITF, 2020)
    - 50 km/h at rural roads
    - 80 km/h at major interurban roads
    - 100 km/h on motorways
- Speeding enforcement should be massively implemented through cameras (always on) and fines massive processing should be efficiently upgraded if necessary with new legislation urgently put in place.
- Intensification of enforcement of mobile-phone use and non-use of seat belts and helmets, eventually with any other COVID-19 related traffic controls.

- Implementation of massive campaigns (within those for the COVID-19) raising public awareness on speeding and the other major traffic accidents factors.

Finally, as everyday life and more specifically travelling and commuting shortly after the lockdown could induce stress on COVID-19 transmission (Porcelli, 2020) policymakers should also seek out alternatives to public transport such as trams, metros and buses. It is hoped that allocating road space to bicycles and pedestrians, and reducing the space available for cars, will encourage people to cycle or walk rather than taking the car (ITF 2020).

Safer road traffic and no accidents should be the first priority during and after the COVID-19 pandemic. The current circumstances must act as the trigger for a new and serious behavior by both the authorities and citizens for safer roads for all, everywhere in the world.

7 Bibliography

Anderson, R.M., Heesterbeek, H., Klinkenberg, D., Hollingsworth, T.D., 2020. How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet 395, 931–934.

Apple, 2020. COVID-19 - Mobility Trends Reports - Apple [WWW Document]. Apple. URL https://www.apple.com/covid19/mobility (accessed 5.9.20).

Cai, J., Xu, Bo, Chan, K.K.Y., Zhang, X., Zhang, B., Chen, Z., Xu, Bing, 2019. Roles of different transport modes in the spatial spread of the 2009 influenza A(H1N1) pandemic in mainland China. Int. J. Environ. Res. Public Health 16, 1–15.

Clarke, S., 2020. The traffic data that shows the road into - and out of - Covid-19 lockdown _ World news _ The Guardian. Guard.

De Vos, J., 2020. The effect of COVID-19 and subsequent social distancing on travel behavior. Transp. Res. Interdiscip. Perspect. 5, 100121.

ETSC, 2020. COVID-19_ Cities adapting road infrastructure and speed limits to enable safer cycling and walking [WWW Document]. URL https://etsc.eu/covid-19-cities-adapting-road-infrastructure-and-speed-limits-to-enable-safer-cycling-and-walking/?utm_source=ETSC&utm_campaign=6b633809a6-Safety_Monitor_121&utm_medium=email&utm_term=0_3a7b55edbf-6b633809a6-103253801 (accessed 5.9.20).

Garten, R.J., Davis, C.T., Russell, C.A., Shu, B., Lindstrom, S., Balish, A., Sessions, W.M., Xu, X., Skepner, E., Deyde, V., Okomo-adhiambo, M., Gubareva, L., Barnes, J., Smith, C.B., Emery, S.L., Hillman, M.J., Rivailler, P., Smagala, J., Graaf, M. De, Burke, D.F., Fouchier, R.A.M., Pappas, C., Alpuche-aranda, C.M., López-gatell, H., Olivera, H., López, I., Myers, C.A., Faix, D., Blair, P.J., Yu, C., Keene, K.M., Jr, P.D.D., Boxrud, D., Sambol, A.R., Abid, S.H., George, K.S., Bannerman, T., Ginsberg, M., Kriner, P., Waterman, S., Smole, S., Guevara, H.F., Belongia, E.A., Clark, P.A., Beatrice, S.T., Donis, R., Katz, J., Finelli, L., Bridges, C.B., Shaw, M., Jernigan, D.B., Uyeki, T.M., Smith, D.J., Klimov, A.I., Cox, N.J., 2009. Antigenic and Genetic Characteristics of Swine-Origin 2009 A(H1N1) Influenza Viruses Circulating in Humans. Science (80-.). 325.

Google LLC, 2020. Google COVID-19 Community Mobility Reports [WWW Document]. URL https://www.google.com/covid19/mobility/ (accessed 5.9.20).

Hazen, A., Ehiri, J.E., 2006. Road traffic injuries: Hidden epidemic in less developed countries. J. Natl. Med. Assoc. 98, 73–82.

ITF International Transport Forum, 2020. Re-spacing Our Cities For Resilience.

Molloy, J., 2020. MOBIS Covid19 Mobility Report [WWW Document]. URL https://ivtmobis.ethz.ch/mobis/covid19/reports/mobis_covid19_report_2020-06-04.html

Porcelli, P., 2020. Fear, anxiety and health-related consequences aFter the coVid-19 epidemic. Clin. Neuropsychiatry 17, 103–111.

Sharma, B.R., 2008. Road traffic injuries: A major global public health crisis. Public Health 122, 1399–1406.

TomTom, 2020. COVID-19 response | TomTom [WWW Document]. URL https://www.tomtom.com/covid-19/ (accessed 5.9.20).

World Health Organization, W., 2018. Global Status Report on Road Safety 2018.

World Health Organization, W., 2020. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. WHO Dir. Gen. speeches.

Worldometer, 2020. Worldometer Coronavirus Update (Live) [WWW Document]. URL https://www.worldometers.info/coronavirus/ (accessed 5.9.20).

Xu, Bo, Tian, H., Sabel, C.E., Xu, Bing, 2019. Impacts of road traffic network and socioeconomic factors on the diffusion of 2009 pandemic influenza a (H1N1) in mainland China. Int. J. Environ. Res. Public Health 16, 1–14.

Zhang, D., Hu, M., Ji, Q., 2020. Financial markets under the global pandemic of COVID-19. Financ. Res. Lett. 101528.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., Wang, D., Xu, W., Wu, G., Gao, G.F., Tan, W., 2020. A novel coronavirus from patients with pneumonia in China, 2019. N. Engl. J. Med. 382, 727–733.