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COVID-19 lockdown and reduction of traffic accidents in Tarragona province, Spain

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ABSTRACT

This paper analyses the impact that the lockdown decreed by the Spanish Government to combat the spread of COVID-19 has had on traffic accidents in Tarragona province (Spain). During the studied period of the lockdown (March 16 - April 26 2020) the number of accidents per day fell by 74,3% in coparison with those in February 14-20 (reference week) and 76% in respect to the equivalent period in 2018-2019. This reduction of accidents has been higher than the decrease of mobility during the same reference period (62.9%). This suggests a multiplicative positive effect of traffic reduction on roads safety. Our findings provide new evidences of the disruptive effect of the COVID-19 pandemic on transportation and of how it could be used as a catalyst to promote more sustainable and secure transport systems.

1. Introduction

The year 2020 will be remembered for the COVID-19 pandemic, which has infected several million people (confirmed cases) around the world, causing hundreds of thousands of deaths. Some national governments responded by imposing lockdowns in order to reduce the spread of infection and potential deaths, but this had negative economic and social repercussions (unemployment, business bankruptcies, etc.) (Béland et al., 2020) and raised the question of what the main priority should be: public health or the economy? One of the restrictions introduced limited personal mobility, as air and land traffic were two of the main vectors for the dissemination of COVID-19 (Kraemer et al., 2020; Lau et al., 2020; Peeri et al., 2020; Wu et al., 2020). Important restrictions on mobility were applied (Beck and Hensher, 2020; Chinazzi et al., 2020; De Haas et al., 2020; Engle et al., 2020; Hadjidemetriou et al., 2020; Loske, 2020; Stavrinos et al., 2020) with the aim of controlling the spread of the disease. This response included limiting non-essential travels and the closure of centres of education.

One of the negative consequences of mobility is traffic accidents, with the resulting material damage and economic losses (Hsu et al., 2015; Kopits and Cropper, 2005); others include social costs, physical injuries and, in the worst case, even deaths. Every year, around 1.35 million people are killed on road all around the world; in fact, this is the eighth leading cause of death and also results in up to 50 million injuries each year (WHO, 2019). One positive effect of the measures implemented to control the spread of COVID-19 was the reduction of traffic accidents, on both urban and interurban roads (Aloi et al., 2020; Brodeur et al., 2020; Shilling and Waetjen, 2020); this resulted in a marked fall in the number of traffic-related injuries and fatalities, as observed by Christey et al. (2020), Oguzoglu (2020), and Nuñez et al. (2020).

Among the main factors behind traffic accidents are environmental conditions (weather, visibility, etc.), road characteristics, vehicle design, human error, and the volume of vehicles circulating on our roads (Retallack and Ostendorf, 2019). In some cases, traffic accidents are due to a combination of more than one of the above. The probability of traffic accidents occurring increases with the volume of vehicles on our roads and in line with certain road characteristics (Cadar et al., 2017; Martin, 2002; Wang et al., 2013a). This probability increases in situations characterized by both low and high levels of congestion (Retallack and Ostendorf, 2019; Sun et al., 2016; Wang et al., 2013b; Zhou and Sisiopiku, 1997). In the latter case, however, the severity of the resulting accidents tends to fall when vehicles crash at lower speeds (Casado-Sanz et al., 2020; Shefer, 1994). The restrictions on mobility introduced following the COVID-19 outbreak have implied a sharp reduction in road traffic. This should have had a direct and noticeable effect.

These restrictions on mobility have also fostered certain environmental improvements. One such example concerns air quality; this has improved due to a reduction in the pollutants discharged into the atmosphere as a

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result of socio-economic activity and the use of motor vehicles (Aloi et al., 2020; Anjum, 2020; Arora et al., 2020; Brodeur et al., 2020). Mobility has positive social and economic impacts, but it can also produce environmental problems, such as noise, air pollution and greenhouse gas emissions, all of which adversely affect human health (Carrier et al., 2016; Chapman, 2007; Héritier et al., 2017; Mueller et al., 2017; Schwanen, 2019). Cleaner air resulting from traffic restrictions introduced in response to COVID-19 has had positive implications for human health (Isalfan, 2020; Nelson, 2020). Even so, these changes have so far implied only immediate and short-time improvements. When normal activity resumes, old challenges are likely to re-emerge.

The State of Alarm decreed by the Spanish Government (BOE, 2020) came into force on March 16th. Citizens throughout the country subsequently had certain of their activities restricted, including their mobility. According to the Spanish Directorate-General for Traffic (DGT, 2020), during the first six weeks of lockdown, interurban traffic in Spain decreased by 72%, with notable differences between weekdays (−65%) and weekends (−86%). This included a drastic reduction in urban traffic, so the corresponding reduction in traffic accidents was perhaps only to be expected.

Taking all of these circumstances into account, our main objective was to analyse the impact that the COVID-19 lockdown had on traffic accidents. Tarragona province (in North-East Spain) was chosen as a study case. The reduction in the number of traffic accidents in the region was analysed, as were more specific details, including their: (1) territorial location, (2) severity, (3) distribution between weekdays and weekends/holidays, and (4) the types of road (urban or interurban, and different types of interurban roads) on which they occurred. This research will contribute new evidence to the growing literature on the multiple effects of the COVID-19 pandemic on transportation around the world.

2. Data and methods

2.1. Area of study

Tarragona is a province of 800,000 inhabitants whose population is predominantly concentrated along the coast and in and around its two main cities (Fig. 1): Tarragona (134,000) and Reus (104,000). It has no other settlements with over 50,000 inhabitants, and only eight others with >20,000: Amposta, Calafell, Cambrils, Salou, Tortosa, Valls, El Vendrell and Vilaseca. The area's economy is dominated by the presence of the largest petrochemical complex in southern Europe and the fact that the *Costa Dorada* is an important tourist destination. The southern part of the province is an area of notable agricultural production, associated with water from the River Ebro.

The territory is crossed by several motorways, including the AP7 and AP2 (Fig. 1). The former follows the coastline, communicating Barcelona and the South of France, to the northeast, with Valence and much of Spain's southern Mediterranean coast area to the southwest. The AP2 connects the AP7 in the east of the province to such cities as Zaragoza and Madrid to the west. The most important conventional basic road in terms of daily traffic intensity is the N340, which runs parallel to the AP7. The section of the N340 between Tarragona and the Vandellòs nuclear power station was subsequently replaced by a new motorway: the A7. Another

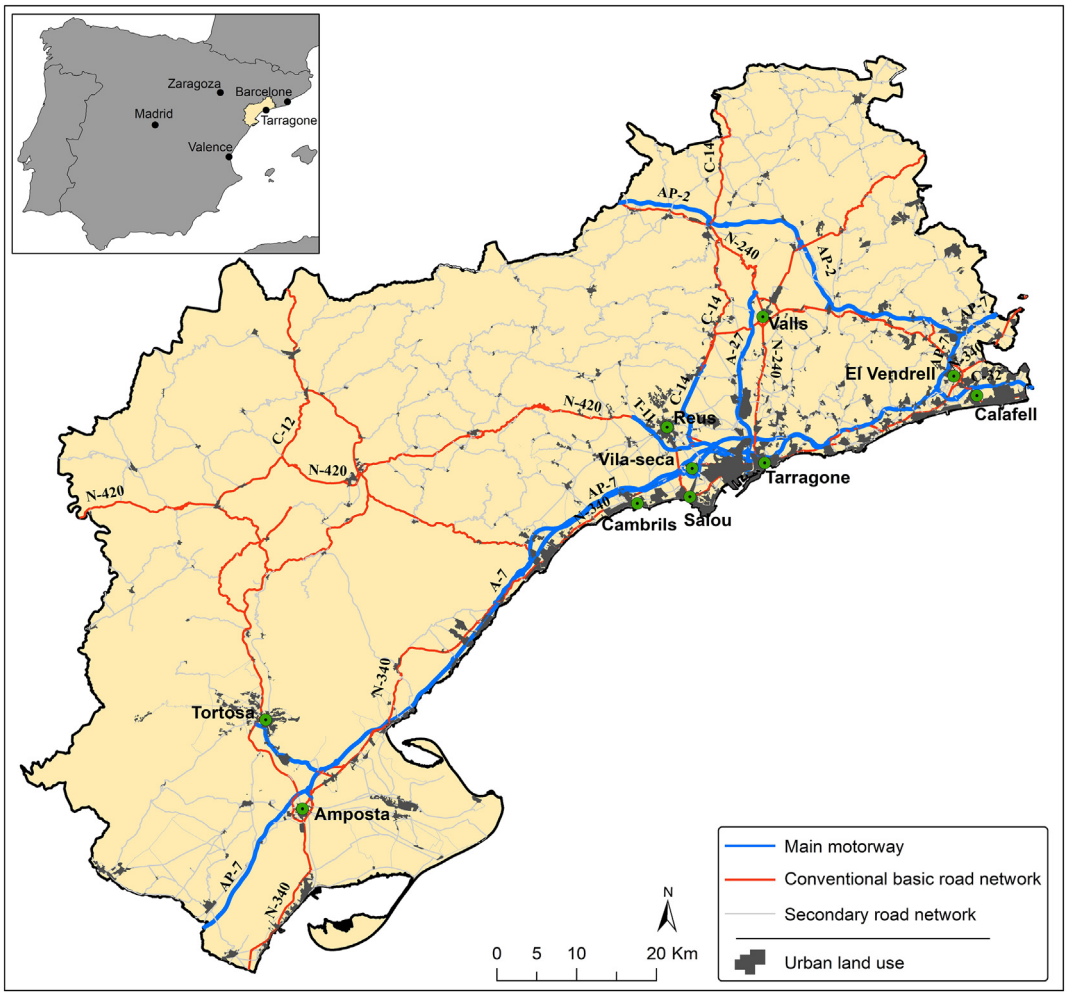

Fig. 1. Area of study.

important conventional basic road is the N420, which begins in Reus and provides communication with Zaragoza, to the west.

It is also relevant to highlight four other major roads that cross the territory from north to south. These are (from east to west): the N240 (a conventional basic road); the A27 (a motorway with the same characteristics as the A7); the C14 (a conventional basic road with a section of dual carriageway); and the C12 (a conventional basic road, often referred to as the Ebro Axis, which runs parallel to the River Ebro), which crosses the southern part of Tarragona province. Another major roadway is the T11, which is an interurban motorway, running between Tarragona and Reus.

2.2. Data and methods

The data on traffic accidents were obtained from the Directorate-General of Fire Prevention, Extinction and Rescue (DGPEIS) of the *Generalitat de Catalunya* (the Autonomous Government of Catalonia) and included information from the Catalan Fire Department. The information was not fully complete because some traffic accidents are only dealt with by the police. Our database did, however, include all the road accidents with the most severe repercussions in terms of material and economic damage, injuries, and fatalities.

The dataset covered the period from Monday, February 3, to Sunday, April 26, 2020: a total of 84 days (12 weeks). The first six weeks corresponded to the period immediately before the lockdown (Monday, February 3 – Sunday, March 15) and the other six to that after of lockdown (Monday, March 16 – Sunday, April 26). The first period included 30 weekdays and six weekends (12 days). The second period included only 28 working days due to the Easter holidays. The DGPEIS also provided data on traffic accidents for the equivalent periods in 2018 (Monday, February 5 – Sunday, April 29) and 2019 (Monday, February 4 – Sunday, April 28). The distribution of days between weekdays, weekends and holidays was the same as in 2020.

The following information was provided for each traffic accident:

- Date (day, month, and year)
- Municipality
- Road code (interurban traffic accidents)
- Street name (urban traffic accidents)
- Injured or trapped victims
- UTM coordinates.

We did not, however, receive any information concerning the times of the accidents, the collision speeds, or the numbers and characteristics of the vehicles involved in these accidents.

We compared the number of traffic accidents and daily averages both before and after the lockdown in 2020 with those that took place during the equivalent period in 2018–2019, following a similar approach to those used by Aloi et al. (2020) and Shilling and Waetjen (2020). The chi-square test ($\chi 2$) was then applied to analyse whether the differences in the distribution of the traffic accidents were statistically significant. The same analysis was performed for the severity of the accidents and whether they occurred on weekdays or at weekends/holiday, on urban or interurban roads, and according to the typology of the roads on which they took place: motorway, conventional basic road, or secondary road.

The distribution of the accidents was correlated with the reduction in mobility in the same area and during the same period. To do this, we used data on daily mobility in Tarragona province that were collected via mobile phone traces and compiled by the Spanish Ministry of Transport, Mobility and Urban Agenda. In that case, the available data for each day took into account the mobility flows for a reference period chosen by the same Ministry (February 14–20) with value 100.

Finally, in order to analyse if the lockdown had also implied a different spatial pattern of accident distribution, we used a Kernel Density Estimation function to calculate the concentration of traffic accidents both before and during the lockdown period. This estimation computes a magnitude per unit area, based on point or polyline features, using a kernel function to fit a smoothly tapered surface to each point or polyline. This enabled us to produce a series of heat maps showing the highest and lowest concentrations of accidents in each of the periods studied. Kernel Density Estimation is a well-established technique for conducting studies using Geographical Information Systems and spatial-analysis approaches to reveal the spatial patterns of road accidents and injuries (Anderson, 2009; Bíl et al., 2013; Hashimoto et al., 2016; Xie and Yan, 2013, among others).

3. Results

3.1. Traffic accidents and severity

A total of 192 traffic accidents involving the intervention of the Catalan Fire Department took place during the 84 days covered by the study (Table 1). The daily average was 2.3. The number of traffic accidents registered during these 12 weeks represented a decrease of 34% compared to the average for the equivalent period in 2018–2019. However, it should be underlined that the lockdown began in the middle of the period analysed (on March 16). Table 1 shows the number of traffic accidents and the daily average for the six weeks before lockdown and also for the first six weeks of the lockdown period. The pre-lockdown period was associated with almost four of every five traffic accidents recorded (3.6 per day). The average number of daily traffic accidents during the lockdown period fell to 0.9 and the total number of traffic accidents fell by 74%.

A comparison with 2018–2019 confirmed the effect that the lockdown had on traffic accidents, although the overall distribution during the equivalent periods in 2018–2019 was not so different. The number of traffic accidents that occurred during the lockdown fell by 76% compared to the equivalent period in 2018–2019 and the difference in the distribution of traffic accidents before and after the lockdown (2018–2019 versus 2020) was statistically significant ($\chi 2 = 61.47$; $p < 0.001$).

These results were consistent with the global reduction in mobility. Fig. 2 shows the daily mobility flows in Tarragona province from February 29 to April 26, 2020. It was possible to observe an immediate reduction in mobility from Saturday, March 14, which was when the lockdown starting on Monday, March 16 was officially announced by the Spanish Prime Minister. Using the average flows for February 14 to 20 as a reference, the overall daily reduction in mobility corresponding to our study period after lockdown (March 16 to April 26) was 62.9%. Moreover, the reduction of traffic accidents for the same period, and taking into account the same reference week, was 74.3%.

Fig. 3 shows the marked fall in traffic accidents comparing the situations before (top) and during (bottom) lockdown, whereas Fig. 4 shows the concentration of traffic accidents during the same two periods. Before the lockdown, the metropolitan areas of Tarragona and Reus exhibited very high concentrations of traffic accidents. In addition to their high population densities, both cities also receive a large number of commuters (workers and students), as well as other people visiting them for shopping or leisure purposes. Fig. 4 shows the influence of these two motorways on the concentration of traffic accidents in the Tarragona to El Vendrell area (moving north-eastwards) and in the Tarragona to Amposta area (heading south-westwards). It also shows the concentrations along the C14 and A27, respectively running northwards from Reus and Tarragona to the Valls area. These three areas could be considered secondary hotspots in terms of the concentration of traffic accidents.

When lockdown began, the number of traffic accidents fell by three-quarters, with the maximum concentration, as expected, being in the

Table 1
Traffic accidents and daily mean (DM) for the whole period, for before, and for during the lockdown: 2018–2019 and 2020.

	Before lockdown		Lockdown		Whole period	
	Total	DM	Total	DM	Total	DM
2018–2019[a]	125 (43.1%)	3.0	165 (56.9%)	3.6	290	3.4
2020	152 (79.2%)	3.9	40 (20.8%)	0.9	192	2.3

[a] 2018–2019: equivalent period to 2020 (here and in all tables).

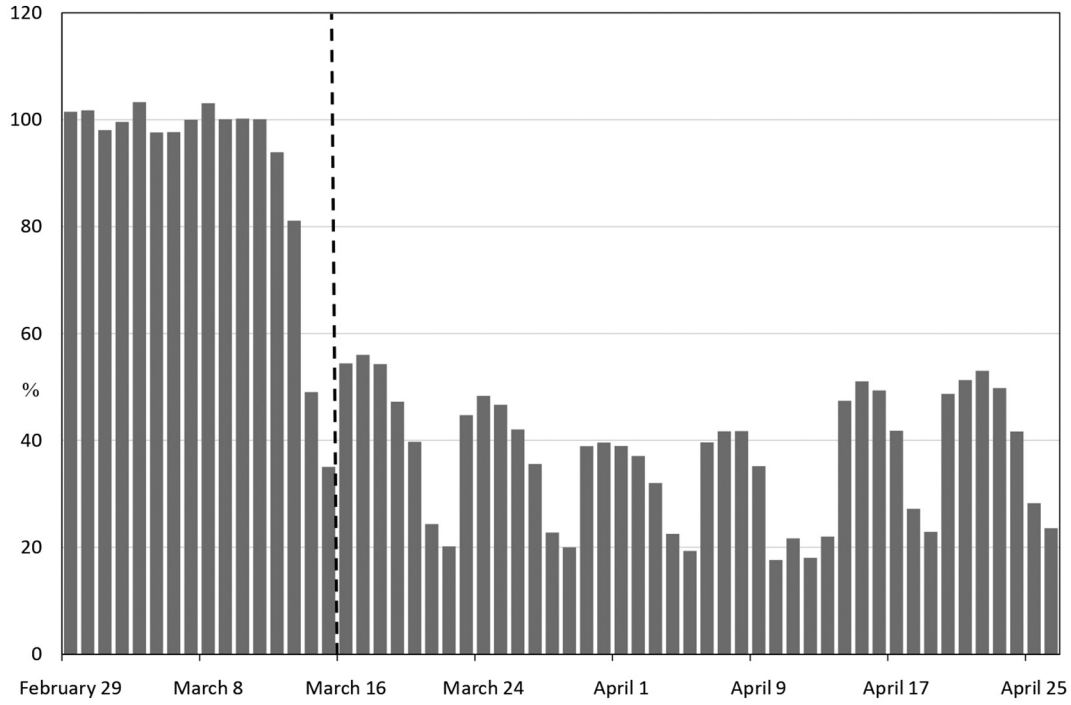

Fig. 2. Daily mobility in Tarragona province (from February 29 to April 26, 2020) regarding to the average mobility from February 14 to 20 (100).

metropolitan areas of Tarragona and Reus. Nevertheless, the concentration rates were lower than before lockdown. The red, orange and yellow surfaces vanished. The Valls area remains as the only secondary hotspot on the map in Fig. 4 (bottom).

Fig. 5 shows the weekly evolution of traffic accidents in 2018–2019 and 2020. Note that in 2018–2019, the last four weeks of the study period had the most traffic accidents (due to more mobility, coinciding with the Easter holidays). In 2020, the lockdown had a clear impact, especially in the seventh (March 16–22; the first week of lockdown) and eleventh (April 13–19; which included Easter Monday, which is a public holiday in Catalonia) weeks. There was also a slight decrease in the number of accidents in the sixth week (the last week before lockdown); this was probably because mobility started to decline during the weekend of March 14–15, once the Spanish Prime Minister announced that the lockdown would begin on the following Monday (March 16). Finally, it is relevant to highlight the increase in traffic accidents in the twelfth, and last, week of the study period (April 20–26). This coincided with restrictions on certain activities being lifted and the consequent increase in mobility.

Table 2 shows traffic accidents, taking into account their severity. Most of these accidents involved people being injured or trapped. The distribution remained very similar during the two periods in 2018–2019, but the total number of accidents increased in the latter in both categories. In contrast, the relative frequency of severe traffic accidents diminished during lockdown, because the fall in these accidents was greater (−77%) than in those in which no-one was injured or trapped (−50%). The difference was statistically significant when traffic accidents involving injured or trapped victims in 2020 (both before and during lockdown) were compared with those corresponding to the equivalent periods in 2018–2019 ($\chi 2 = 57.86$; $p < 0.001$).

3.2. Weekdays and weekends/holidays

Table 3 shows the distribution of traffic accidents taking into account whether they occurred on weekdays or at weekends/holidays. More than two thirds occurred at weekdays in 2018–2019. This matches the distribution of days between weekdays and weekends/holidays; as a result, the daily averages were almost identical (3.4–3.5). This ratio was different in 2020, when the average daily incidence of accidents on weekdays was higher (2.5–1.7).

The reduction in the number of traffic accidents at weekends/holidays (−85%) was more intense than on weekdays in 2020. Nevertheless, the greatest difference was observed when we compared weekend/holiday accidents during lockdown to the equivalent periods in 2018–2019 (−89%). These differences were statistically significant when we compared the distributions for the whole periods in 2018–2019 and 2020 ($\chi 2 = 3.89$; $p < 0.05$) and between the lockdown period and the equivalent period in 2018–2019 ($\chi 2 = 5.98$; $p < 0.05$).

This reduction in the number of accidents was consistent with the reduction in mobility during the latter period (Table 4). Moreover, the reduction in the number of accidents was greater than the overall reduction in mobility. According to data from the Spanish Ministry of Transport, Mobility and Urban Agenda, the reduction in mobility in the province of Tarragona on weekdays during the lockdown was 55.4% compared to the reference period chosen by the Spanish Ministry of Transport, Mobility and Urban Agenda (week of February 14–20). The reduction of accidents was 67.2% for the same days. By the other hand, the reduction of mobility flows corresponding to weekends and holidays during the same period was 77.8%, while the reduction of traffic accidents was 88.4%.

3.3. Urban and interurban roads

Table 5 shows the distribution of traffic accidents taking into account whether they occurred on urban or interurban roads. Accidents on interurban roads accounted for >70% of the total. Accidents are more frequent on interurban roads than on those in cities and towns. The reduction in the number of traffic accidents over the whole study period, comparing 2020 with 2018–2019, was greater on urban than on interurban roads (−48% and −29%, respectively).

The incidence of urban and interurban traffic accidents rose during the second period in 2018–2019; this was especially true of urban traffic accidents. Nevertheless, and as expected in a typical situation, the difference in their distributions was not statistically significant ($\chi 2 = 0.86$). In 2020, the reductions in the number of traffic accidents during the lockdown period were very similar on urban and interurban roads (75% and 73%,

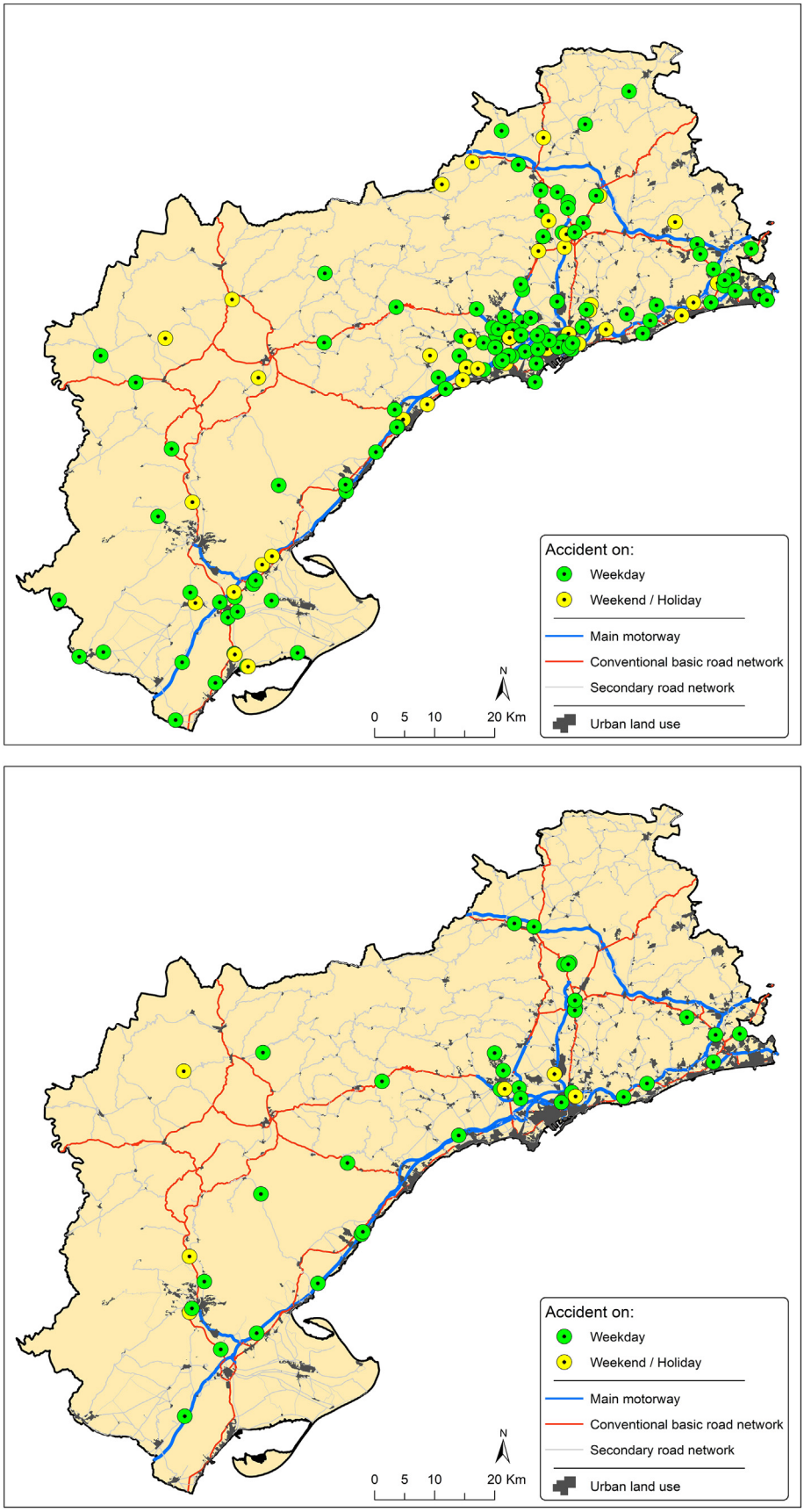

Fig. 3. Spatial distribution of traffic accidents in Tarragona province before (top map) and during (bottom map) lockdown.

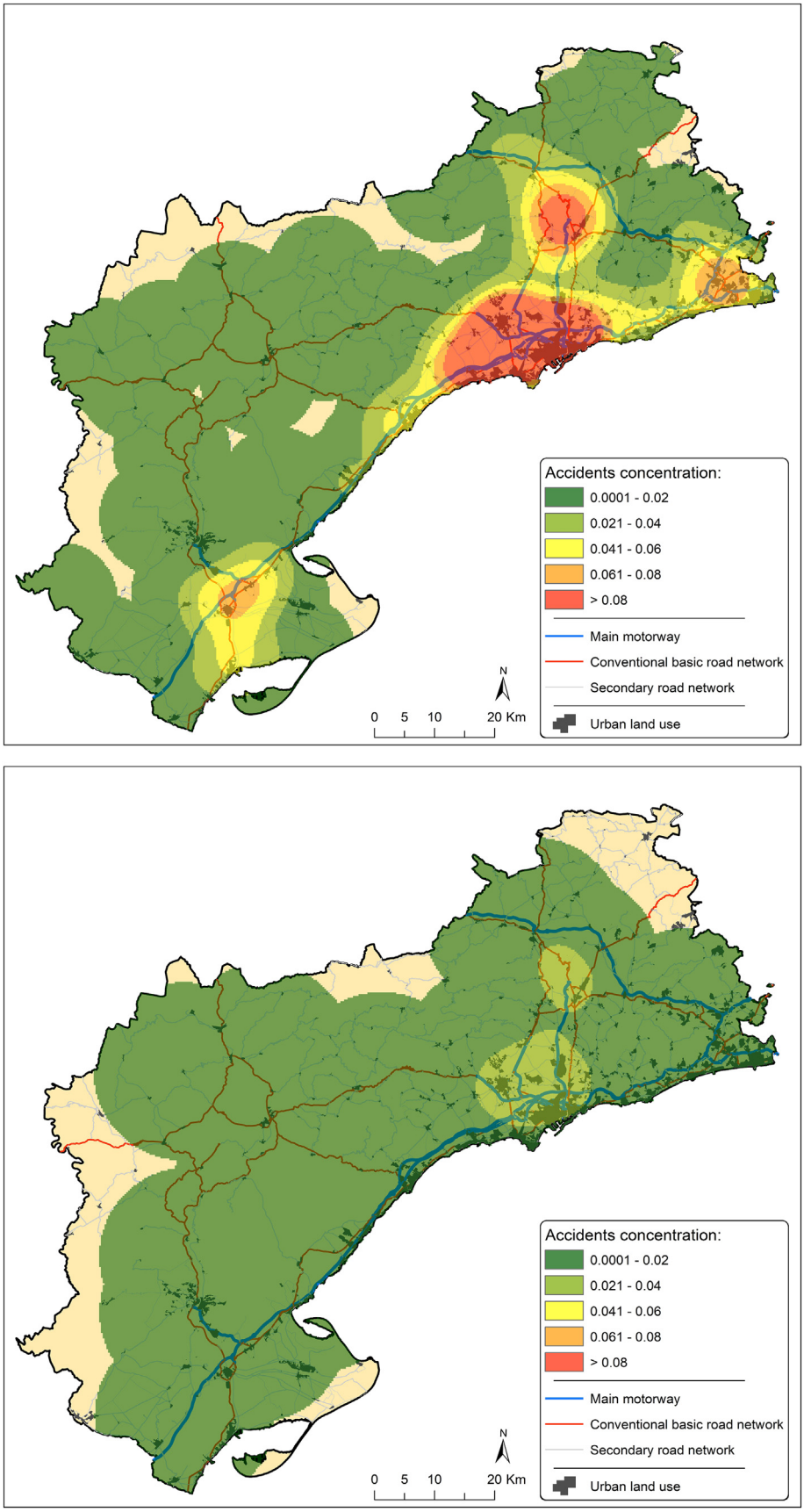

Fig. 4. Concentration of traffic accidents in Tarragona province before (top map) and during (bottom map) lockdown.

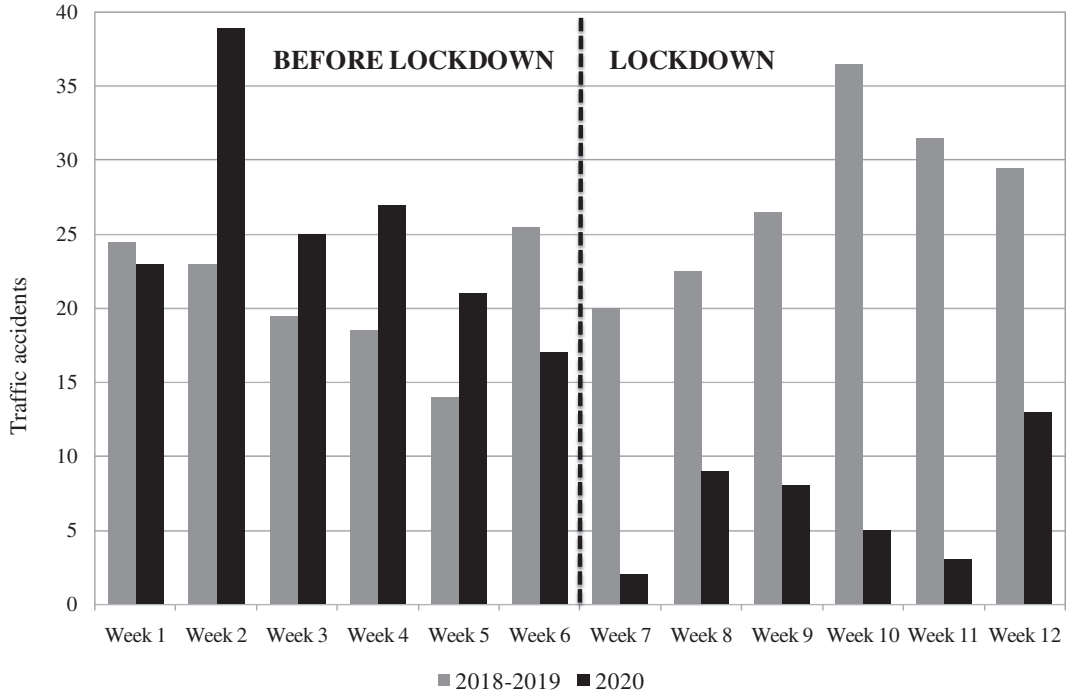

Fig. 5. Weekly distribution of traffic accidents: 2018–2019 and 2020.

respectively). The reduction in mobility due to COVID-19 might have been expected to produce a greater decrease in the number of traffic accidents in urban areas, where speeds are lower, but this hypothesis was not supported by the data analysed.

Despite the dramatic decrease in the number of traffic accidents on both urban (−83%) and interurban (−73%) roads, when the lockdown period was compared to the equivalent periods in 2018–2019, the differences in distribution were not statistically significant ($\chi 2 = 1.22$).

The inhabitants of Tarragona and Reus account for 29% of the total population of Tarragona province. During the 12 weeks analysed for 2018–2019, three out of every 10 traffic accidents on urban roads occurred in one of these two cities. The total number of accidents declined during the same period in 2020, but its relative weight increased to 37%. The same pattern was found when we compared the periods before and during the lockdown in 2020: one in three before lockdown, but one in two during lockdown.

Table 6 shows the distribution of traffic accidents, highlighting whether they occurred on motorways, on conventional basic roads, or on secondary roads. During the 12-week periods corresponding to 2018–2019, almost half occurred on conventional basic roads and particularly on the N340 (which has a high frequency and intensity of vehicles, one lane of traffic moving in each direction, and a speed limit of 90 km/h). The number of traffic accidents in 2020 declined for all three road typologies, but especially on conventional basic roads (−41%); even so, road accidents remained most frequent on these roads, although the distribution was quite balanced.

In 2020, the number of traffic accidents decreased on all three types of road networks when comparing the periods before and during lockdown. This reduction was especially evident on secondary roads (−89%) and motorways (−69%). As a result, despite the evident decrease in the number of road accidents on conventional basic roads (−59%), the relative weight of traffic accidents on these roads actually increased from 43.2% to 50%. Nevertheless, the difference in their distribution was not statistically significant ($\chi 2 = 5.97$[1]); this was also the case when we compared the period before the lockdown with the equivalent periods in 2018–2019 ($\chi 2 = 4.70$).

Table 2
Traffic accidents and severity: 2018–2019 and 2020.

		Before lockdown	Lockdown	Total
2018–2019	Injured/Trapped	115 (92.0%)	147 (89.1%)	262 (90.3%)
	Not Injured/Trapped	10 (8.0%)	18 (10.9%)	28 (9.7%)
2020	Injured/Trapped	136 (89.5%)	32 (80.0%)	168 (87.5%)
	Not Injured/Trapped	16 (10.5%)	8 (20.0%)	24 (12.5%)

Table 3
Traffic accidents on weekdays and at weekends/holidays: 2018–2019 and 2020.

		Before lockdown	Lockdown	Total
2018–2019	Weekdays	92 (72.4%)	106 (65.0%)	198 (68.3%)
	Weekends/Holidays	35 (27.6%)	57 (35.0%)	92 (31.7%)
2020	Weekdays	113 (74.3%)	34 (85.0%)	147 (76.6%)
	Weekends/Holidays	39 (25.7%)	6 (15.0%)	45 (23.4%)

4. Discussion

Our findings show that the lockdown decreed by the Spanish Government on March 14, 2020, as a measure to drastically reduce the spread of COVID-19 disease, produced a significant reduction in traffic accidents in Tarragona province. While the number of traffic accidents may vary from year to year, or even season to season, the tremendous difference in the number occurring during the study period in 2020 and equivalent periods in 2018–2019, as also between the periods before and during lockdown, could mainly be attributed to the lockdown. The probability of having a traffic accident is higher when there are more vehicles on the roads. Moreover, our findings indicate that the degree of traffic accidents reduction has been higher than the reduction of mobility flows in the province. This would suggest than a reduction of transit in the roads should have a multiplicative effect in the reduction of accidents and injuries.

The number of traffic accidents registered in early spring is greater than in late winter under normal circumstances. This is due to an increase in mobility in spring, mainly associated with travel for leisure and tourism (more

[1] It would be statistically significant if $\chi 2 > 5.99$.

Table 4
Traffic accidents during the lockdown with respect to the reference period February 14–20 (value 100) and daily average.

February 14–20 (reference week)		Lockdown period (March 16–April 26)	
Mobility flows per day	Accidents per day	Mobility flows per day	Accidents per day
100	100 (3.7)	37.1	25.7 (0.9)
March 16–April 26 (weekdays)		**March 16–April 26 (weekends/holidays)**	
Mobility flows per day	Accidents per day	Mobility flows per day	Accidents per day
44.6	32.8 (1.2)	22.2	11.6 (0.4)

Table 5
Traffic accidents on urban and interurban roads: 2018–2019 and 2020.

		Before lockdown	Lockdown	Total
2018–2019	Urban	30 (23.8%)	47 (28.7%)	77 (26.6%)
	Interurban	96 (76.2%)	117 (71.3%)	213 (73.4%)
2020	Urban	32 (21.1%)	8 (20.0%)	40 (20.8%)
	Interurban	120 (78.9%)	32 (80.0%)	152 (79.2%)

hours of sunlight and nicer weather), which is particularly relevant at weekends. In addition, the Easter holidays coincided with the second period, which normally implies more vehicles on the roads and therefore an increase in the number of accidents. In fact, there were more traffic accidents during the pre-lockdown period in 2020 than in the equivalent periods corresponding to 2018–2019. An increase in traffic accidents was therefore to be expected in spring 2020. However, the lockdown changed this pattern. This change was consistent with phenomena reported by Shilling and Waetjen (2020), who compared the incidence of traffic accidents before and during the lockdown in California, and by Brodeur et al. (2020), whose study covered five US states. Safer-at-home policies reduced the number of traffic collisions and hence the number of people killed or seriously injured on the road.

The number of traffic accidents involving people being injured or trapped fell more noticeably than less severe collisions. According to the Catalan Traffic Service (SCT, 2020), the number of road accident deaths registered in February 2020 was 17% higher than in the previous year, yet 74% lower in March 2020. In fact, the number of road accident fatalities registered in Tarragona province fell by 41% from January to April 2020. The lockdown modified the expected trend of more road deaths and injuries in 2020 than in the two previous years. The mobility restrictions introduced to curb the spread of COVID-19 disease therefore led to a reduction in traffic accidents, and especially the severest ones. This was consistent with the findings reported by Christey et al. (2020), who analysed road transport-related admissions to a level one trauma centre in New Zealand over two 14-day periods, before and during the lockdown for COVID-19: a 74% fall in admissions due to traffic accidents. According to Oguzoglu (2020), Turkish Government's introduction of stricter rules in April 2020 produced a significant fall in the number of people injured (19%) and killed (72%) in traffic accidents in Turkey. Nuñez et al. (2020) analysed visits to the emergency trauma department of a tertiary hospital that forms part of the Spanish National Health System, following the same approach as that used in the present study (analysing the period before and during lockdown and the equivalent periods in 2018 and 2019). They found that the number of people injured in traffic accidents fell by 79% when they compared the periods before and during the lockdown and also when these were compared to the equivalent periods in 2018–2019.

Table 6
Traffic accidents on interurban networks: 2018–2019 and 2020.

		Before lockdown	Lockdown	Total
2018–2019	Motorways	31 (32.6%)	28 (23.7%)	59 (27.7%)
	Conventional basic	41 (43.2%)	53 (44.9%)	94 (44.1%)
	Secondary roads	23 (24.2%)	37 (31.4%)	60 (28.2%)
2020	Motorways	36 (30.0%)	11 (34.4%)	47 (30.9%)
	Conventional basic	39 (32.5%)	16 (50.0%)	55 (36.1%)
	Secondary roads	45 (37.5%)	5 (15.6%)	50 (32.9%)

The number of traffic accidents fell, both on weekdays and at weekends/holidays, but the fall was more pronounced on non-working days. This could be attributed to the fact that the mobility needed to provide basic services, such as the distribution of food and other goods, was not as restricted as for other activities (e.g., leisure), and that accidents associated with the former mainly occur on weekdays. Nevertheless, in both cases (weekdays and weekends or holidays) the reduction of accidents has been higher than the reduction of mobility flows.

It is important not to forget the anomalous effect of the Easter holidays: in a normal year, they imply thousands more vehicles on the roads and a consequent increase in the number of serious accidents. The differences between 2018–2019 and 2020 can mainly be explained by the lockdown, which seemed to have greater repercussions on the number of accidents occurring at weekends/holidays than on weekdays. The results for 2018–2019 reinforce the argument that, in a typical year, there are more traffic accidents in spring than in winter, and especially at weekends/holidays, for all the reasons argued above.

The number of traffic accidents decreased on both urban and interurban roads, but especially the former. In the case of urban roads, the entities that benefitted the most from the lockdown period, in terms of the fall in traffic accidents, were small towns and villages, which usually have lower traffic densities. In the case of interurban roads, when comparing the lockdown period and the corresponding periods in 2018–2019, the greatest reduction in serious accidents was observed on basic conventional roads when comparing the period during the lockdown and the equivalent periods in 2018–2019 but on secondary roads when comparing the periods before and during lockdown in 2020. Even so, the anomalous effects that measures to combat the COVID-19 crisis had on the incidence of traffic accidents did not cause any significant changes to their distribution patterns.

5. Conclusions

5.1. Implications of our findings and main contributions

The ongoing COVID-19 pandemic is having a major impact on health, but has also affected numerous economic and social phenomena on an almost unprecedented scale. It is currently affecting almost all facets of society, modifying our lifestyle and general behaviour. Mobility has been no exception in this respect, and even more so when modern society is characterized by hypermobility at multiple scales (Cohen and Gössling, 2015). Mobility declined significantly in all countries when lockdowns were imposed, as in the case of Spain. Nevertheless, the restrictions placed on mobility gradually evolved in the weeks after the lockdown began, allowing the mobility of a larger numbers of people and activities in later weeks. Unfortunately, this also led to an increase in traffic accidents and in the resulting deaths and injuries. In the case of Tarragona province, our findings revealed an upward trend in traffic accidents in the last week of the study. Furthermore, the number of traffic accidents would then probably have continued to increase with respect to the equivalent period in previous years, due to more private vehicles being driven due to a possible reluctance to use public transportation (Aloi et al., 2020; De Vos, 2020;

Gutiérrez et al., 2020; Musselwhite et al., 2020), associated with maintaining social distance.

There is a real risk that the clearly positive impacts of restricted mobility on traffic accidents could only remain in the short term. The same could apply to the benefits for human health associated with the reduction in atmospheric pollution, improved air quality, and reduced noise levels that have been linked to the COVID-19 crisis, especially in cities. In fact, Isalfan (2020) has argued that, in the case of China, the lockdown imposed by the government may have saved more lives by reducing air pollution (all sources considered) than it has done by preventing the spread of infection.

The unexpected benefits of the COVID-19 crisis will therefore probably only persist if the lockdown is maintained (which is neither expected nor desired) or if new public policies are designed and implemented with the objective of facilitating a gradual change in patterns of production, mobility, and consumption. COVID-19 offers both an opportunity and a challenge for public administrations (at the national, regional, and municipal levels) to apply policies designed to reduce mobility (King and Krizek, 2020). Our findings reveal that decrease of mobility implies a higher decrease of accidents and injuries. This happens in the whole studied period. Moreover, as higher is the reduction of mobility (weekends or holidays) higher is the relative differential with the decrease of accidents and injuries.

Serafimova (2020) also considers that the pandemic may help to pave the way for the introduction of more sustainable, integrated, and reliable transportation system. Teixeira and Lopes (2020) have shown that, in the case of New York, bicycle sharing schemes were apparently able to improve the resilience of urban transport systems in response to disruptive phenomena such as COVID-19. Similar targets are not new and had already been widely discussed before the COVID-19 pandemic (Khreis et al., 2016; Khomenko et al., 2020; Nieuwenhuijsen and Khreis, 2019; Stevenson et al., 2016). COVID-19 has, however, made a difference. As a result, Budd and Ison, 2020 have proposed the new concept of *Responsible Transport* which "delivers safe, secure and equitable mobility that embeds social, economic and environmental wellbeing at the heart of post-COVID transport policy, planning and operations and enables individuals to make considered transport choices". The same authors have outlined a series of debates and decisions that should involve local citizens in the search for the most suitable modes of transport.

COVID-19 may serve as the catalyst that helps to shift policies on mobility (particularly in cities) towards more environmentally friendly and citizen-focused solutions. According to Nieuwenhuijsen and Khreis (2017), cities should become partly private car-free, reduce motorized traffic, invest in cycling infrastructure and pedestrianization, restrict parking spaces, and increase the availability of public transport. Such initiatives would reduce mobility associated with private motor vehicles, but also the number of traffic accidents and levels of urban pollution. This could be achieved in a planned and negotiated way, instead of being abruptly imposed, and would therefore contribute to meeting UN Sustainable Development Goals 3 (Good health and well-being), 11 (Sustainable cities and communities) and 13 (Climate action).

5.2. Limitations of the present study and the agenda for future research

The main limitations of our study derived from the data source used. As mentioned in the data and methods section, the information available to us made it possible to geolocate serious accidents and injuries and to determine the days on which they occurred. We did not, however, have information about the exact time of each accident, the speed at which it took place, the typologies of the vehicles involved, or the number of people involved, among other relevant factors. Similarly, we lacked access to new data after the lockdown. As a result, the evolution of cases after the progressive reestablishment of mobility has not been reported in this study. Taking these limitations into account, and also a series of new questions arising from our research, we feel that a number of interesting issues remain to be investigated in future research.

The evolution of traffic accidents after the lockdown period should be studied. At the time of writing the current article, new outbreaks of disease were reappearing in different parts of Spain. As a consequence, several new, partial mobility, restrictions were applied in provinces neighbouring Tarragona. It would therefore be interesting to compile a continuous and dynamic report on: measures taken to restrict mobility; the evolution of mobility flows; and their influence on the increase/decrease in road traffic accidents. Results from this case study could provide useful insights and lessons for other parts of Spain. On the other hand, a growing number of studies are already highlighting the disruptive effects that the pandemic has had on travel behaviour, at multiple scales, around the world. As a consequence, it has been underlined that the pandemic could become a catalyst for medium to long-term changes in mobility and transportation at the local and global levels (Budd and Ison, 2020; De Vos, 2020; Gutiérrez et al., 2020; Koehl, 2020; Laverty et al., 2020). Within a context of uncertainly regarding the future evolution of the pandemic and its impact on human mobility, it is difficult to predict the potential direct and indirect effects on traffic accidents. In a global context of varying definitions of travel behaviour, it would seem appropriate to study the evolution of traffic accidents with respect to the "new normality" and with different societal and territorial contexts.

CRediT authorship contribution statement

Òscar Saladié: Conceptualization, Methodology, Formal analysis, Writing original draft, reviewing original draft, Editing final manuscript. **Edgar Bustamante**: Formal analysis, Cartography. **Aaron Gutiérrez**: Conceptualization; Formal analysis, Reviewing original draft. All authors have approved the final version.

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