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Population Mobility Trends and Road Traffic Safety in the Republic of Croatia Respecting the Covid-19 Pandemic

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ABSTRACT

Early in the spring of 2020, the COVID-19 disease pandemic occurred, and European Union members made the decision to restrict their borders to protect the public's health. Demand for travel and transportation services has decreased as a result of the epidemiological scenario brought on by the movement restriction. The research focuses on how mobility affects traffic safety in the Republic of Croatia, considering the conditions of the COVID-19 pandemic, with the aim of limiting human movement and contact in order to safeguard human health. In this paper, relevant traffic indicators and their effects on road traffic safety are analysed with the aim of analysing the effects of the Covid-19 pandemic on mobility and traffic safety. The study compares safety indicators during different time periods, including before, during, and after the removal of restrictions prompted by a pandemic. The research aims to assess the impact of the pandemic on traffic safety and mobility patterns, providing valuable insights for future planning practices that incorporate emerging knowledge. The research aims to promote pedestrian and bicycle traffic, reduce air pollution, and contribute to global initiatives aimed at achieving road safety goals. Moreover, it offers a potential solution to help achieve the European policy targets for road mobility and safety by 2030.

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1 Introduction

The declaration of the COVID-19 pandemic in March 2020 remains a persistent threat to public health. This worldwide health crisis has resulted in the implementation of measures that restrict everyday mobility, impacting various sectors of society adversely. The implementation of strategies such as practicing social and physical distancing, alongside timely interventions in mobility, played a significant role in mitigating the spread of the pandemic prior to the availability of a vaccine.

The various modes of transportation, such as air, rail, road, and water, have experienced significant impacts. Passenger and freight transport were also severely affected due to complex supply and demand trends. This study aims to present empirical evidence regarding human mobility patterns by examining their correlation with road safety indicators. The analysis covers the period from 17 February 2020 to December 31, 2022, comparing safety indicators before, during, and after the lifting of restrictions imposed in response to the pandemic declaration in the Republic of Croatia.

The research aims to evaluate the impact of the pandemic on mobility patterns and traffic safety, which are essential indicators for future planning. It seeks to contribute valuable insights regarding the creation of new knowledge in the field. Official statistics remain the benchmark for monitoring over time, but the crisis caused by the COVID-19 virus has forced policymakers and statisticians to consider new types of data sources. The effectiveness of these policies in reducing human mobility can be observed through the analysis of data presented in COVID-19 mobility reports by companies such as Google and Apple. By utilizing anonymous data from applications like Google Maps, a continuously updated dataset has been generated, illustrating the changes in people's movement patterns during the pandemic.

2 Methodology and resources

Governments worldwide have implemented a variety of stringent measures to combat the pandemic, including stay-at-home orders, closure of schools and workplaces, cancellation of events and public gatherings, and limitations on public transportation. Valuable insights regarding these measures can be gleaned from the community mobility reports provided by Google and Apple. Google's community mobility reports provide mobility information that compares actual values to baseline values while accounting for visits and length of stays across various geographies. These are anonymized data taken from Apple and Google services like Google Maps. [1] If someone has enabled location history settings, which were enabled by default in Google services, they are included in the globally collected data. Strong anonymization methods were utilized to process all data from Google and Apple.

Association of Croatian American Professionals consulted government, media, United Nations, and other organisations sources and categorized the data into the following categories:

- social distancing,
- movement restrictions,
- public health measures,
- social and economic measures,
- lockdowns. [4]

The following Table 1 presents the measures of restriction and prohibition of movement implemented during the lockdown caused by the Covid 19 pandemic in the Republic of Croatia.

Table 1 Policy measures considered in the analysis of population mobility trends in the Republic of Croatia respecting the Covid-19 pandemic

Category	Measure	Description
Movement restrictions	Additional health or other document requirements upon arrival	Authorities upon arrival to a country may request a health declaration format or doctor's certifications to allow entry.
	Border checks	Authorities may travel and identification document checks at land and sea entry points in a country.
	Border closure	A country may close the land or sea border with the neighboring countries. Only nationals and residents are allowed through.
	Complete border closure	A country has completely closed the borders for all – including nationals.
	Checkpoints within the country	Authorities may have installed checkpoints within the country on regional borders or main roads to a) conduct health checks and b) stop the internal movement of people.
	International Flights suspension	Government authorities may suspend international and/or internal flights.
	Domestic travel restrictions	Authorities are limiting the movement of people within a country.
	Visa restrictions	Authorities are limiting specific nationalities from entering the country or they are adding visa restrictions that did not exist before.
	Curfews	Introducing curfews in some regions or in the whole country.
	Surveillance and monitoring	Authorities may conduct electronic surveillance via mobile phones or other ways to do case tracing or to monitor the movement of people.
Social and economic measures	Economic measures	Authorities have taken economic measures in order to mitigate the impact of the other restrictions on the economy and society.
	Emergency administrative structures activated or established	Authorities have put in place emergency administrative structures such as Emergency Response committees etc. in order to coordinate the response and/or decide on measures and/or monitor the implementation.
	Limit product imports/exports	Authorities are limiting the import or export of either food or health items.
	State of emergency declared	Authorities have declared a state of emergency. Usually, this measure is used to be able to implement other measures that are not allowed by constitutions in a regular situation. This may also include state of necessity, exceptional state and state of public health emergency.
	Military deployment	The military has been deployed to support medical operations and ensure compliance with the measures.
Lockdown	Partial lockdown	Partial lockdown includes: The population cannot leave their houses for specific reasons that they have to communicate to the authorities. All stores that are not related to alimentation or pharmacies are not open.
	Full lockdown	Full lockdown includes: The population cannot leave their houses for specific reasons that they have to communicate to the authorities. All non-essential services closed and production stopped.
	Lockdown of camps	Limitations to the population living in camps and/or camp like conditions.

Source: [6]

Table 2 Description and data source of mobility reports categories

Category	Description	Data Source
Retail and recreation	Restaurants, cafes, shopping centers, theme parks, museums, libraries, and movie theatres.	Google
Grocery and pharmacy	Grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies.	Google
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens.	Google
Transit stations	Public transport hubs such as subway, bus, and train stations.	Google
Workplace	Places of work.	Google
Residential	Places of residence.	Google
Driving	Driving mobility of Apple users	Apple
Walking	Walking mobility of Apple users	Apple

Source: [8]

Community mobility reports, which showcase travel patterns across different locations, have been published by a leading technology company. These reports depict movement trends over time across various categories, including retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential areas (Table 2).

The description and data source of the mobility report categories in Table 2 show, which locations were tracked according to which categories. It is also stated which data was tracked by Google and which by Apple.

3 Analysis of mobility trends in the Republic of Croatia respecting the Covid-19 pandemic

Community mobility reports, showcasing travel patterns across different locations, are published by a well-known company. These reports present changes in each category within an area using two distinct approaches. The mobility for the report date is compared to a reference day and presented as a positive or negative percentage calculated specifically for that date. The company has developed a regularly updated dataset that demonstrates the changes in people's travel behaviors during the pandemic, utilizing anonymized data from applications such as Google Maps. As part of the implemented measures, restrictions on personal movement were imposed due to the significant role of air and road travel in the spread of COVID-19.

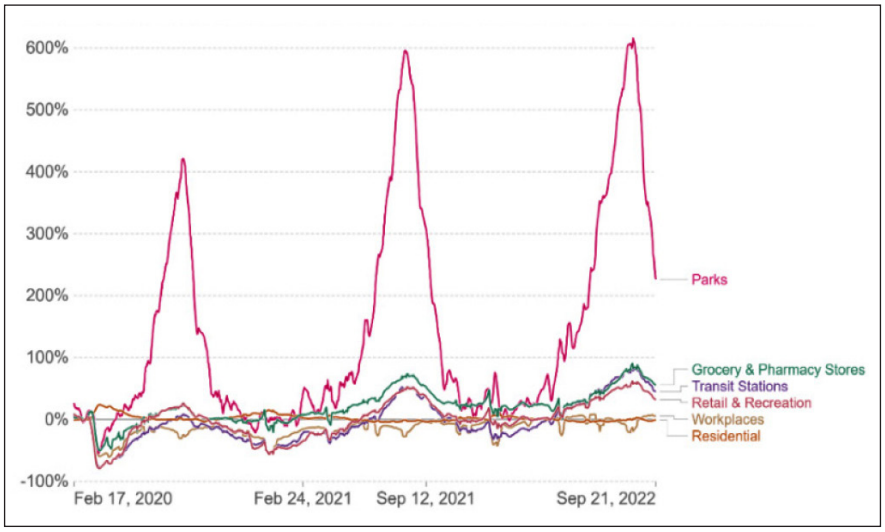
A dataset provided by a technology company monitors daily visitor counts for specific types of locations, comparing them to pre-epidemic levels. Baseline days are established by averaging typical values for each day of the week over a five-week period from January 3 to February 6, 2020. Similarly, Apple has released COVID-19 pandemic data related to mobility, akin to Google's efforts. Apple collects this data by analyzing requests for directions made through Apple Maps, which is accessible at both national and major city levels worldwide. Apple has also made available time series data for different nations and locations, focusing on two modes of transportation: driving and walking.

3.1 Community mobility in the Republic of Croatia

In accordance with the defined goal of the research, this part analyzes mobility trends in the Republic of Croatia according to specific locations and types of movement in the analyzed time period. Graph 1 illustrates the comparison between the base volume recorded on January 13, 2020 and the relative volume of driving and walking requests in the Republic of Croatia over a three-year period (2020, 2021, and 2022). On March 14, 2020, preventive measures were implemented in certain regions of the country, followed by a nationwide initiation of store closures and cancellation of public events on March 19, 2020. In an effort to contain the spread of the disease, the National Headquarters issued a directive on March 21, 2020, which imposed restrictions on gatherings in streets, squares, and other public spaces, as well as the suspension of public transportation. [5]

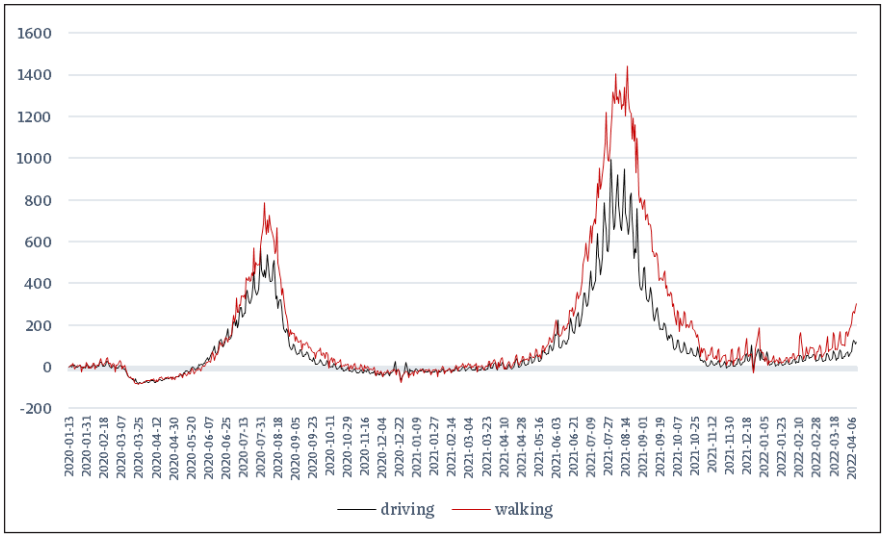
The most significant decline in mobility was observed on March 23, 2020, coinciding with the restriction on movement to one's place of residence or permanent residence. The National Headquarters implemented a partial relaxation of pandemic protection regulations on April 27, 2020, as a measure to stimulate the economy. This makes it possible for all commercial enterprises that engage in trade activity to do so, with the exception of those that run shopping malls. On May 11, 2020, the third phase of lowering epidemiological measures started, allowing some students to return to school. After almost two months, retail centers, cafes, and restaurants started operating. As a result, long-distance roads, trains, and domestic flights are established. Graph 2 shows the trends in the movement of passengers from January 2020 to April 2022 in the Republic of Croatia.

The reduction of epidemiological measures leads to increased driving and walking mobility, which reached its maximum in August 2020 due to the large number of tour-



Graph 1 Community movement in specific locations in the Republic of Croatia

Source: [9]



Graph 2 Mobility Trends Report from the Republic of Croatia

Source: [10]

ists. At the end of September and the beginning of October 2020, the number of infected people will increase, so measures will be reintroduced, such as the suspension of classes in schools and colleges, restaurants and cafes will be closed, and restrict the public events, which leads to a sharp decrease in mobility shown in the chart. [1]

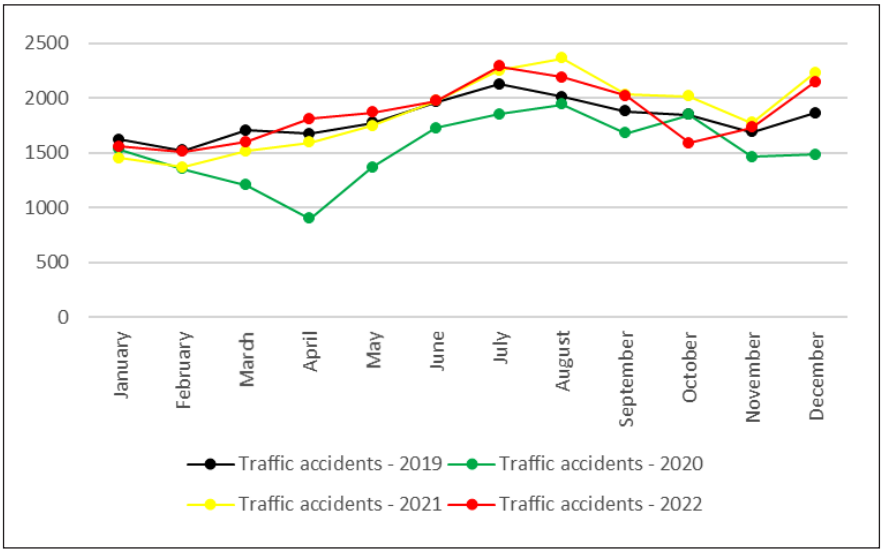
3.2 Traffic safety in the Republic of Croatia in correlation with COVID-19 pandemic

The Croatian Ministry of the Interior takes care of the state of road traffic safety. In order to make this part of the work as successful as possible, the conditions and changes in road safety are systematically monitored. [3] The outcomes of this study present statistical data that offer an enhanced and comprehensive understanding of the road safety conditions in the Republic of Croatia, along with all the associated risk factors. The paper compares the number of traffic accidents before, during, and after the removal of measures implemented during the COVID-19 pandemic. Table 3 shows the total number of road accidents in the Republic of Croatia for the period 2019-2022. According to the current data on traffic safety for 2019 in the Republic of Croatia, negative trends can be highlighted.

Table 3 Traffic accidents in the Republic of Croatia for the period 2019-2022

Month	Traffic accidents – 2019	Traffic accidents – 2020	Traffic accidents – 2021	Traffic accidents – 2022
January	1624	1534	1452	1560
February	1522	1354	1371	1512
March	1705	1208	1515	1602
April	1672	900	1596	**1808**
May	1776	1371	1747	**1869**
June	1962	1725	**1974**	**1974**
July	2125	1852	**2252**	**2287**
August	2012	1941	**2363**	**2189**
September	1877	1677	**2032**	**2019**
October	1845	1849	**2018**	1589
November	1688	1466	**1772**	**1730**
December	1864	1487	**2230**	2147

Source: [11], [12], [13], [14]



Graph 3 Number of traffic accidents by year in the Republic of Croatia for period 2019-2022

Source: Authors

In terms of mortality rate, 297 people were killed in reported traffic accidents, which is well above the EU average. As opposed to the steady decrease in the European Union since 2001, the mortality rate in the Republic of Croatia has fluctuated over this period. When the number of vehicles is considered into account, the Republic of Croatia also performs worse than other EU countries with a rate of 1.47 fatalities per 10,000 registered vehicles. Over the past ten years, the number of fatalities in the Republic of Croatia has fallen by 30%, which is more than the decrease in the European Union. The number of serious injuries in Croatia dropped by 22% over the same period. [7]

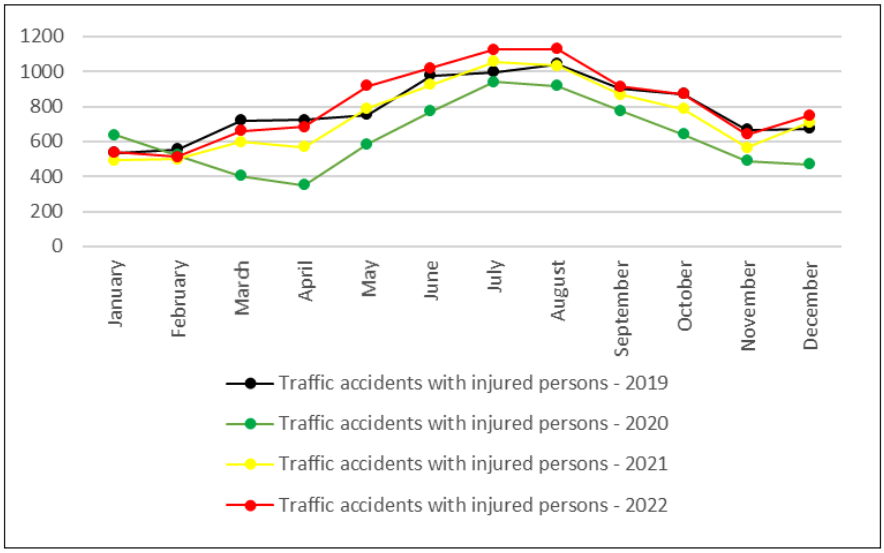
Graph 3 will present trends in traffic accidents in the Republic of Croatia in the period 2019-2022.

Traffic accidents continue to pose a significant threat to public safety and have far-reaching consequences for individuals and societies. This analysis focuses on the Republic of Croatia, where a concerning trend has emerged—a rise in traffic accidents by 614 incidents from 2019 to 2022. This increase translates to a percentage change of approximately 2.84%. To tackle this issue effectively, it is crucial to conduct an in-depth examination of the contributing factors driving this negative trend.

Table 4 Traffic accidents with injured persons in the Republic of Croatia for period 2019-2022

Month	Traffic accidents with injured persons – 2019	Traffic accidents with injured persons – 2020	Traffic accidents with injured persons – 2021	Traffic accidents with injured persons – 2022
January	536	**636**	491	**539**
February	556	521	498	513
March	720	402	597	661
April	723	349	569	682
May	753	585	**788**	**917**
June	976	773	923	**1021**
July	997	939	**1057**	**1125**
August	1042	918	1031	**1129**
September	903	775	868	**915**
October	870	639	784	**872**
November	667	490	566	639
December	673	469	**711**	749

Source: [11], [12], [13], [14]



Graph 4 Number of traffic accidents with injured persons by year in the Republic of Croatia for the period 2019-2022

Source: Authors

During the four-year period, significant fluctuations in the number of traffic accidents involving injured individuals were observed. The year 2019 marked the highest recorded number of such accidents (9,416), while 2020 witnessed the lowest (7,496). Subsequently, the number of accidents increased in 2021 to 8,883, reaching its peak in 2022 with 9,762 traffic accidents involving injured persons.

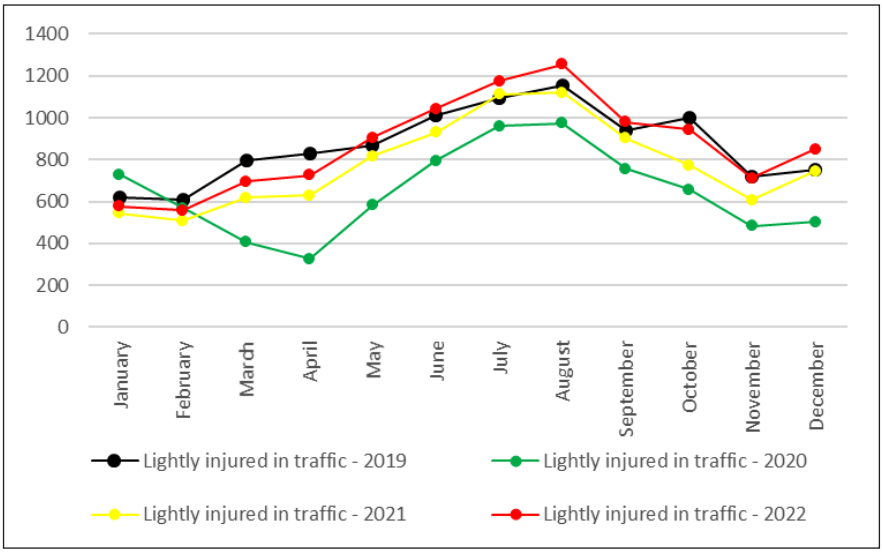
From a statistical perspective, there is a marginal rise in the number of traffic accidents involving injured individuals in 2022 compared to 2019. Precisely, there has been an increase of 346 such accidents during that time frame, which corresponds to approximately a 3.7% surge in their occurrence between the mentioned years. To obtain a comprehensive understanding of the influence of the Covid-19 pandemic on road traffic safety, it is crucial to analyze traffic accidents resulting in minor consequences throughout the period of 2019-2022 (Table 5).

Between 2019 and 2020, there was a decrease in the number of slightly injured persons by 2653 or approximately 25.5%. However, between 2020 and 2021, the number of slightly injured persons increased by 1568, which represents an increase of about 20.3%. The trend of an increasing number of slightly injured individuals contin-

Table 5 Traffic accidents with slightly injured in traffic in the Republic of Croatia for period 2019-2022

Month	Slightly injured in traffic – 2019	Slightly injured in traffic – 2020	Slightly injured in traffic – 2021	Slightly injured in traffic – 2022
January	622	**729**	544	578
February	611	570	507	558
March	794	405	618	696
April	828	326	630	726
May	869	584	817	**904**
June	1009	795	930	**1042**
July	1092	959	**1112**	**1176**
August	1153	974	1121	**1254**
September	941	757	903	**980**
October	1002	656	773	943
November	720	483	608	713
December	752	502	745	849

Source: [11], [12], [13], [14]



Graph 5 Number of traffic accidents with slightly injured in traffic by year in the Republic of Croatia for period 2019-2022

Source: Authors

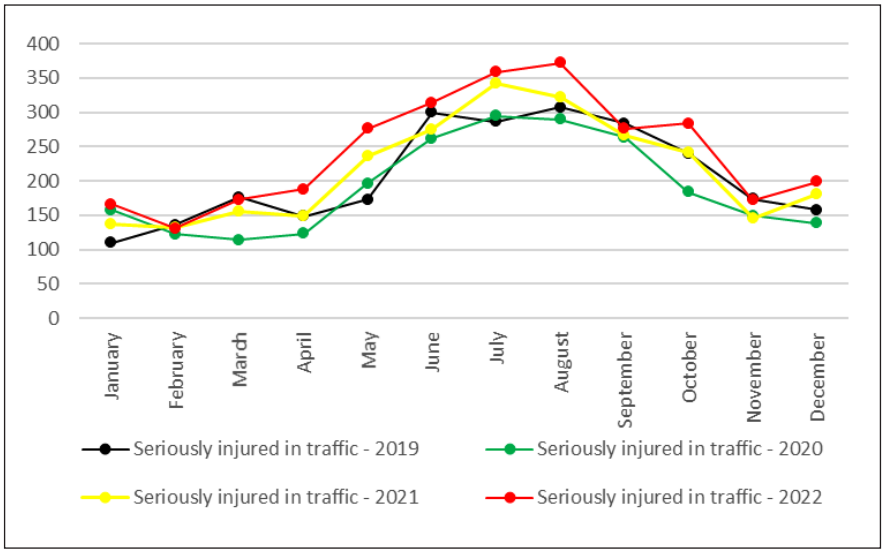
ued from 2021 to 2022, with a further rise of 1,111 cases or approximately 11.9%. Graph 5 showcases the trends in the number of traffic accidents resulting in slight injuries in the Republic of Croatia for the period of 2019-2022.

In a comprehensive analysis comparing the period before the COVID-19 pandemic in 2019 and the period after the easing of measures in 2022, it can be seen that the number of slight injuries in traffic accidents increased slightly by 26, which represents an approximate increase of only 0.25%.

Table 6 Traffic accidents with serious injuries in traffic in the Republic of Croatia for the period 2019-2022

Month	Seriously injured in traffic – 2019	Seriously injured in traffic – 2020	Seriously injured in traffic – 2021	Seriously injured in traffic – 2022
January	110	**158**	**137**	**166**
February	136	122	132	131
March	176	114	156	173
April	148	123	148	**188**
May	173	**196**	**236**	**276**
June	300	262	275	**314**
July	286	**295**	**342**	**359**
August	307	290	**322**	**372**
September	284	264	266	276
October	240	184	**242**	**284**
November	174	149	145	172
December	158	138	**180**	199

Source: [11], [12], [13], [14]



Graph 6 Number of traffic accidents with serious injuries in traffic by year in the Republic of Croatia for the period 2019-2022

Source: Authors

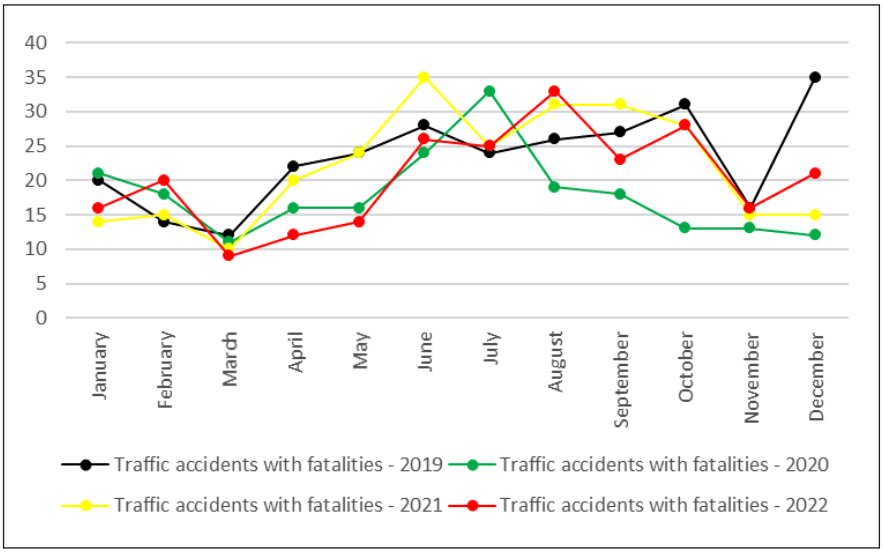
Based on the examination of data concerning the number of seriously injured persons in traffic accidents, the following trends are observed. Between 2019 and 2020, there was a reduction in the count of seriously injured individuals by 197 or roughly 7.9%. However, from 2020 to 2021, there was an increment of 286 in the number of seriously injured persons, signifying an approximate 12.5% rise. This trend persisted from 2021 to 2022, with an additional increase of 329 in the count of seriously injured persons, accounting for approximately 12.7%.

A substantial rise can be observed in the occurrence of traffic accidents resulting in serious injuries in 2022 when compared to 2019. More specifically, there has been a notable increase of 418 instances of traffic accidents involving serious injuries during this period. This surge corresponds to a rise in the incidence rate of such accidents by approximately 16.8% between the mentioned years.

Table 6 Traffic accidents with fatalities in the Republic of Croatia for the period 2019-2022

Month	Traffic accidents with fatalities – 2019	Traffic accidents with fatalities – 2020	Traffic accidents with fatalities – 2021	Traffic accidents with fatalities – 2022
January	20	**21**	14	16
February	14	**18**	**15**	**20**
March	12	11	10	9
April	22	16	20	12
May	24	16	**24**	14
June	28	24	**35**	26
July	24	**33**	**25**	**25**
August	26	19	**31**	**33**
September	27	18	**31**	23
October	31	13	28	28
November	16	13	15	16
December	35	12	15	21

Source: [11], [12], [13], [14]



Graph 7 Number of traffic accidents with fatalities by year in the Republic of Croatia for the period 2019-2022

Source: Authors

Based on the analysis of data concerning the number of traffic accidents resulting in fatalities, the following trends are observed. From 2019 to 2020, there was a decline in the count of fatalities by 65 or approximately 23.3%. However, between 2020 and 2021, there was an increase of 49 in the number of traffic accidents with fatalities, indicating an approximate 22.9% rise. Subsequently, between 2021 and 2022, the number of traffic accidents resulting in fatalities decreased by 20 or approximately 7.6%.

By examining the data on the number of traffic accidents resulting in fatalities in 2019 and 2022, a substantial reduction of 36 fatalities is observed, corresponding to a decrease of approximately 12.9%. This decline in the number of traffic accidents with fatalities serves as a noteworthy indicator of the effectiveness of safety measures and policies that have been implemented to mitigate fatalities in such accidents.

The total number of registered road vehicles in the Republic of Croatia amounted to 2.312.280 in 2020, which was 1.6% more than in 2019. The total number of registered passenger cars amounted to 1.746.285 in 2020, which was an increase of 1.2% compared to 2019. The number of first registrations of road vehicles amounted to 132.572, which was a significant decrease of 31.8% compared to 2019. [2] The decrease in first registrations was recorded for all types of vehicles. The number of registered road vehicles in 2021 was 2,385,442, which is 3.2% more than in 2020. The number of registered passenger

vehicles in 2021 was 1,795,465, which is 2.8% more than in 2020. [15]

In 2022, there were 2,456,017 registered road motor vehicles in the Republic of Croatia, which is 3% more than the year before, while there were 1,840,767 registered passenger vehicles, which is 2.5% more than in 2021. [16]

4 Conclusion

Traffic accidents and traffic injuries are the leading cause of death worldwide. The basic indicators of safety on the traffic network are traffic accidents and their consequences. Based on a thorough examination of the data, this scientific work sheds light on the complex dynamics of mobility trends and road safety conditions in the Republic of Croatia during the period of 2019 to 2022.

Considering the duration of the COVID-19 pandemic, a significant decrease in the number of traffic accidents, as well as the number of slightly and seriously injured individuals and fatalities in traffic, has been observed. This is a result of various factors that have influenced traffic conditions during the pandemic, including movement restrictions, reduced travel, and temporary closure of certain activities. Data analysis shows that traffic accidents, including severe consequences such as severe injuries and fatalities, have decreased during the pandemic. This is likely due to reduced traffic volume, decreased travel, changes in working conditions, and increased awareness of the importance of traffic safety. It is important to note that while the decrease in the number of traffic accidents during the pandemic has been positive, it has not occurred due to the implementation of preventive safety measures or changes in traffic infrastructure. On the contrary, this reduction is a consequence of exceptional circumstances and restrictions that have affected traffic patterns.

The prediction and prevention of traffic accidents cannot be achieved only by the repressive actions of the police. Sanctions for road users who violate traffic regulations must exist and their role is important in maintaining a favorable state of safety. According to the National Road Traffic Safety Program in 2020, the expected number of fatalities should be reduced by 50%; more precisely, from 426 to 213 persons per year. However, in 2022, the number of traffic fatalities is 243. In order to succeed in this – the police must undertake activities with the help of which they will be able to predict and then prevent the occurrence of traffic accidents on the roads.

Society needs to put much more effort into improving road infrastructure and promoting a traffic culture in order to increase the level of road safety. This initiative is mostly the responsibility of the Ministry of the Interior's traffic police, whose operations have an impact on everyone's increased attention to traffic regulations. It is important to investigate how traffic accidents change over time. Only if mobility limits are maintained or if new public policies are developed and implemented to allow for a progressive adjustment in mobility patterns there is a chance that the surprising benefits of the COVID-19 crisis will last.

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Author Contribution: Data Collection, Research, Conceptualization, Methodology, Writing, Review and Editing; all authors contributed equally.

Conflicts of interest/Competing interests: Not applicable.

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