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A Framework and Governance Implications of Real-Time Identification of Traffic Accidents in Cities: Case of Athens

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Biography

Ioannis Poursanidis has graduated from the department of 'Electrical and Computer Engineering' of the Democritus University of Thrace (2011), Xanthi-Greece. He holds a M.Sc. degree in 'Informatics and Management' from the Aristotle University of Thessaloniki (2014), Thessaloniki-Greece. He has experience in designing photovoltaic systems for the low and medium voltage parts of the electricity distribution system. Between December 2016 and December 2020, he had contributed to various tasks performed at the Smart Grid Interoperability Laboratory of the Joint Research Centre of the European Commission, in Ispra-Italy, working initially as a trainee and subsequently as a consultant.

Abstract

In this work, the traffic problems in Athens city are discussed, and a new framework for the real-time identification of traffic accidents in cities is proposed. The framework transcends technological, economic and societal implications of traffic accidents in cities. The requirement of establishing such a system at the city level is clarified, and the technological and organizational means through which the task of the real-time monitoring of traffic accidents can be achieved are described as well. The adoption of the proposed framework could increase the responsiveness and efficacy of city authorities in dealing with traffic accidents in their jurisdictional boundaries, identify any "bottleneck"[1] areas, determine the economic and societal impact of traffic accidents, and act as the basis of informed policy making procedures accounting for undisputable facts[2] regarding the outlook of traffic accidents in a given city. The proposed framework aims to become an indispensable part of the governance structures that the city officials of inclusive, smart and responsive cities utilize both for everyday activities as well as the aggregated inputs needed for investigating a number of alternative policy frameworks to address the challenges posed by traffic accidents' presence.

1 "Bottleneck" areas are defined as the areas where high concentration of traffic accidents is observed.
2 Big data and visualizations of traffic accidents in a citywide scale.

Introduction

Athens[1], a city covering 38.96 km2, is the capital of Greece. The city is considered as the historic capital of Europe that has flourished significantly, in a great number of disciplines including architecture and philosophy, during the Golden Age of Pericles, ca. 5th century B.C.E. Pikoulis et al. (2006) studied the patterns of injuries and motor vehicles traffic accidents in the city of Athens, Greece. Three-year period data were collected and analysed. The most common types of injuries for vehicle and motorcycle accidents have been identified among with the most common reasons for accidents including excessive speed, poor road condition, diver's inattention and use of drugs. High share of injured individuals where not using means of personal protection while driving, i.e. seatbelts and helmets. The authors aimed at developing injury prevention measures and guidelines for reducing traffic accident incidents leading to injuries. A. Theofilatos (2017) studied the incorporation of real-time traffic and weather data for exploring road accidents likelihood and severity in urban arterials focusing on the city of Athens, Greece. The author's findings include that traffic variations act as a significant determinant for accident occurrence while weather conditions did not seem to significantly influence accident occurrence, at least for the given dataset. The ultimate goal of the author was to contribute to the development of traffic management strategies for reducing accident occurrence and severity of injuries in urban arterials. A. Theofilatos et. al (2017), modelled the effects of traffic regimes on safety of urban arterials having as a case study the city of Athens, Greece. A. Theofilatos et. al (2019) studied the impact of real-time traffic accident characteristics on crash occurrence where they considered accidents as rare events. The ultimate goal of the authors was to provide insights on the mechanism governing crash occurrence in motorways. K. Christantonis, et al. (2020) analysed different data manipulation strategies for predicting day-ahead traffic load around cities. Weather data, including humidity, pressure, temperature, wind direction, wind speed, and UV[2] radiation, were collected from distributed sensors in the cities of Athens and Thessaloniki and used as inputs to classification tasks for identifying the main factors affecting traffic prediction in cities. Experimental results presenting different traffic load trends, accounting for seasonal and temporal variation, for the cities considered were illustrated. I. Spyropoulou (2020), studied the impact of public transport strikes on the road network with particular focus on the case of the city of Athens, Greece. Strikes are seen as disruptions affecting the otherwise "normal" traffic flows in and around cities. A number of traffic performance indicators, including increased traffic flows, reduced mean speeds and increased overall travel times, are significantly altered during strike events. The author aimed at designing and implementing targeted countermeasures for mitigating congestion effects in cities. The transportation network of the city of Athens, including metro, rail, tram, bus and trolley bus routes, was presented along with descriptive statistics considering operating hours, annual passengers, and the relative share of each mode of transportation. Traffic flows for normal and strike days were analyzed and presented. The incorporation of the approach presented in this work would lead to the real time collection of data related to traffic accidents in Athens. This situation would, probably, increase the responsiveness of city's authorities leading to higher rescue and treatment rates for the people involved in the traffic accidents.

Generic case presentation

Figure 1 presents the evolution of traffic accidents and affected individuals in Greece as curated by the Hellenic Statistical Authority. Data for the number of accidents as well as the slightly and seriously injured as well as the fatalities, for the considered period, are presented. An overall downwards trend during the data collection period is observed.

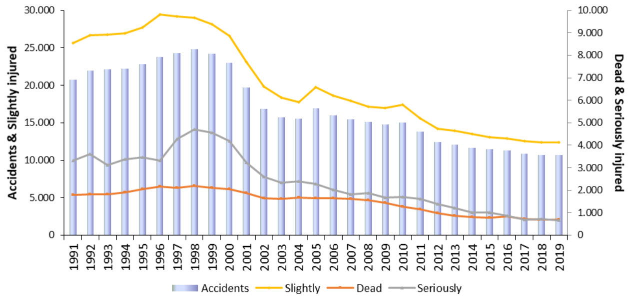


Figure 1. Evolution of number of accidents and affected individuals, between 1991 and 2019, in Greece.

Source: Hellenic Statistical Authority (2019)

1 http://www.visitgreece.gr/en/main_cities/athens
2 Ultraviolet

Figure S1 presents the evolution of fatal and non-fatal traffic accidents in Greece. Overall a downwards trend can be observed. Figure S2 presents the evolution of the number of traffic accidents in the Attica region and the rest of Greece. A downwards trend is observed. Figure S3 presents the number of accidents per type of transportation infrastructure where the traffic accidents took place. The fact that the municipal road infrastructure contributed the most could probable mean that local and regional authorities shall immediately prioritize intervention strategies for altering the situation. Figure S4 presents the evolution of traffic accidents, broken down by region of occurrence, in Greece. The regions of Attica and Central Macedonia contribute the most. The number citizens residing in Attica is around the half the Greek population means that a high number of vehicles is flowing in the cities of Attica, including Athens. Similarly, Thessaloniki as the capital of the region of Central Macedonia provides shelter to around a million of citizens, meaning that a high number of vehicles are flowing in this region as well. The local authorities of Athens and Thessaloniki should further break down the available data into the jurisdictionally responsible cities in order to identify areas of high traffic accidents concentration, determine root-cause relations and prioritize intervention strategies. Figure S5, Figure S6 and Figure S7 present the evolution of traffic accidents accounting for the month, day of week and time of day during which the traffic accidents took place, respectively. An overall downwards trend for all the metrics can be observed. Further statistical analysis could be performed for determining any significant differences between the months, days of week and time of the day of traffic accidents occurrence. Figure S8 presents the evolution of the total number of vehicles involved in traffic accidents in Greece. A downwards trend can be observed. Figure S9 presents the breakdown per type of the vehicles involved in traffic accidents in Greece and its evolution for the considered period. Passenger cars and motorcycles contribute the most to this situation. The advent of IoT components could transform all the vehicles to IoT enabled ones, something that could foster the real-time data collection process when traffic accidents are identified. The introduction of such a technological solution into the vehicle fleet of vehicles flowing in the city of Athens could help putting the citizen to the epicenter of traffic related policy making processes in the city of Athens.

The overall downwards trends in the metrics presented can be attributed to the EU-wide policies for altering the negative consequences of the presence of traffic accidents at local, regional and national level for the EU member states.

Similar statistics, not presented here, are curated for the fatal accidents as well. These data provide insights on the "demographics" of traffic accidents, i.e. sex and age of individuals involved as well as spatiotemporal statistics including the region and time (month and hour) where the accident took place. The incorporation of productivity-related metrics such as profession, income, overall contribution of the individuals involved in traffic accidents to the economic and social development of the region of residence would enhance the capacity of regional and national to determine the overall impact of traffic accidents on the economic and social development of a region.

The fact that an increasing number of urban areas is emerging in the developing World raises questions regarding the governance of transportation infrastructures and the assessment of negative externalities that arise due to the misuse of the infrastructures. An efficient way for monitoring the impact of traffic accidents should constitute an integral part of such developments. The real-time traffic accidents' monitoring system, proposed in this work, can be part of the governance of the smart transportation systems utilized at the level of any given city.

Due to the generic nature of the approach elaborated in this work, no specific information of a given city and the evolution of different variables associated with it will be provided. Instead, a number of different dimensions that employ technological infrastructures needed for the deployment of the technical system that is envisioned in this work will be presented. Any city willing to adapt its governance structure to the framework described in this work can do so by procuring the technical components needed for deploying and maintaining the described monitoring system.

The generic approach adopted in this paper affects three of the four core systems that comprise a city, namely the "city as an economic system", the "city as a social system" and the "city as a technological system". Figure 2 presents the different systems that comprise a city and their relevance to the case study elaborated in this work.

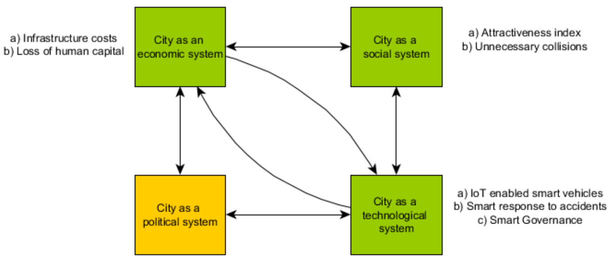


Figure 2. Different systems comprising a city and their relevance to the Case Study presented in this work (adapted from course lectures).

Source: Adapted from Finger M. (2020)

With respect to the "city as an economic system", traffic accidents can cause increase in infrastructural costs for maintaining or replacing damaged infrastructural parts as well as human capital loss since citizens are vital part of capital and value chains in cities. With respect to the "city as social system", traffic accidents can lead to low happiness index due to loss of citizens' life and unnecessary collisions in courts. Finally, with respect to the "city as a technological system", the capacity of real-time identification of accidents through the utilization of signals emitted by IoT enabled smart vehicles can trigger smart, fast and accurate response to accidents and smart governance structures accounting the accumulated impact of traffic accidents. Figure 3 presents a layered depiction of the core components constituting a smart city and their relevance to the case study presented in this work.

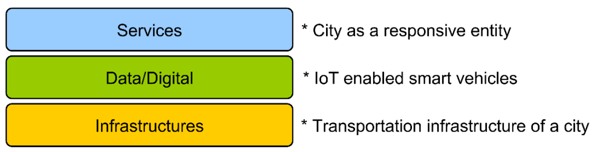


Figure 3. Layered depiction of the core components constituting a smart city relevant to the elaborated case study.

Source: Adapted from Finger M. (2020)

On the "infrastructures" layer, the proposed system will affect the means through which the transportation infrastructure of a city is being monitored. IoT enabled smart vehicles are the prerequisite for gathering the "raw data" needed for real-time response of cities' authorities and mid- and long-term governance adaptations in order to effectively deal with the negative externalities of traffic accidents in cities. At the "services" layer the proposed work transforms the city to a "real-time ready" responsive entity in the service of the citizens. Next, the main problem identification and description of the relevant means through which the proposed framework could be deployed are discussed.

Main problem identification and description

The rapid urbanization of different parts of the world raises plethora of questions regarding how the transportation infrastructure will evolve and/or follow the urbanization procedure. According to M. Finger (2020), inefficiencies in urbanization developments may lead to poor citizen satisfaction from the services that cities offer to them. Poor design of transportation infrastructures may lead to an increased number of traffic accidents or "bottleneck" areas with huge congestions and a big number of accidents.

Figure 4 presents the progression of automation in vehicles according to U.S. DoT[3]. What presented in this figure is relevant to the approzach elaborated in this work since it depicts the stages of introduction of automation functionalities facilitated through the use of Information and Communications Technology (ICT) infrastructure and IoT enabled components. It is expected that, under full automation, there will be no traffic accidents in cities due to the coordinated co-operation of smart vehicles assisted by powerful machine learning and artificial intelligence algorithms. At this point, it has to be highlighted that if "full automation" is proved to be "accident-less", then the framework proposed here will become obsolete; meaning that it can only assist city governance authorities during the transition phase to fully automated vehicles. Still, it makes sense to deploy such a system since the transition towards full automation is not homogeneous around the globe and even in progressed and developed cities still the vast ma-

3 United States Department of Transportation

jority of vehicles are either partially or conditionally automated.

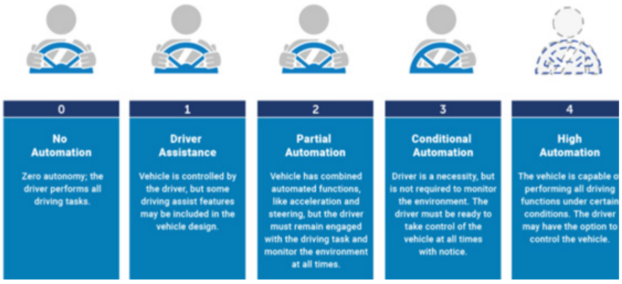


Figure 4. Progression of automation in vehicles according to U.S. DoT. Source: National Highway Traffic Safety Administration, (2020)

Figure 5 presents the implications of vehicle automation under "improved pathway" for different urban layers and the corresponding relevance to the elaborated work. With respect to the infrastructure layer, once a traffic accident status for a smart vehicle is identified as 'True', then the vehicle discloses its coordinates to the closest city, in terms of jurisdictional boundaries. In this way, the relevant infrastructure operators are informed about an incident in the part of the infrastructure under their jurisdiction. With respect to the data layer, the issues, that should be dealt with, include the secure and interoperable data transmission to the relevant operator when an accident is identified. Data should be transmitted securely in order to avoid any interference that could alter the coordinates at which the accident was identified leading to the non-optimal response of the city's authorities. Interoperability is crucial as well since it is the technical prerequisite that guarantees that the recipient of data, i.e. the actors that should respond, will properly receive and consolidate the signals communicated by a smart vehicle. A neutral layer where the mapping of signals sent by vehicles complying with different communication standards with the governance technical systems of cities' authorities should be developed and deployed. Here, the telecommunication companies should step in and clarify the technical requirements that should be met by automobile manufacturers and cities' ICT systems. 5G technology could be investigated for its properness for such a task. Finally, with respect to data ownership, it should be mentioned that since the data disclosed when a traffic accident is identified act as the means through which increased responsiveness from relevant authorities can be anticipated a hybrid model for ownership of such data could be in place, i.e. the data belong to the citizen/owner of the smart vehicle as well as the city within the jurisdictional boundaries of which the accident took place. Geostatistical analysis of such data could pave the way for improved decision-making processes for transportation infrastructure management in cities. With respect to the service layer, the proposed framework could enable increased responsiveness and smart governance of the transportation infrastructure of a city. Being by definition citizen-centric, the proposed approach would incorporate into the governance structures of cities the value of citizen's life no matter if they are residents or visitors within the jurisdictional boundaries of any given city.

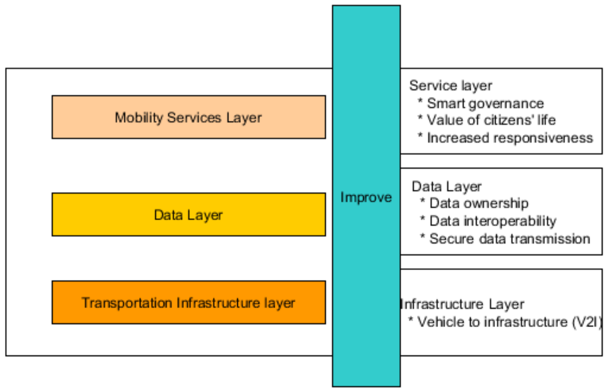


Figure 5. Implications of vehicle automation under improved pathway for different urban layers and the corresponding relevance to the elaborated work.

Source: Adapted from Finger, M. (2020)

For the technical means through which accidents may be identified in real-time, a machine learning model, having as inputs a number of predictors (e.g. vehicles velocity vector, inputs from sensors already integrated in modern smart vehicles e.g. airbag status sensors (on/off), tire pressure sensors (continuous variable), other vehicle sensors and their status, etc.) and as main task to determine whether the vehicle is involved in an accident or not, can be developed. This task can be treated as a binary classification problem (0: no accident, 1: traffic accident) that could be part of the integrated computer that is 'sensing' and 'controlling' the vehicle. The training of the model can take place either in virtual environments or with data collected during emulated crashes of real vehicles that manufactures perform in order to get certificates of compliance regarding the safety of vehicles' drivers and passengers when exposed to traffic accidents.

Figure 6 illustrates a generic process for the determination of vehicles' accident status. When an accident is identified, then the longitude and latitude of the vehicle is disclosed through the use IoT infrastructure to the real-time traffic monitoring system of the considered city. A chain of response actions is triggered. This includes the mobilization of traffic police, fire and emergency services in order to minimize the response time of the authorities, and thus increase the probability of having more people rescued and sent to hospitals for further treatment.

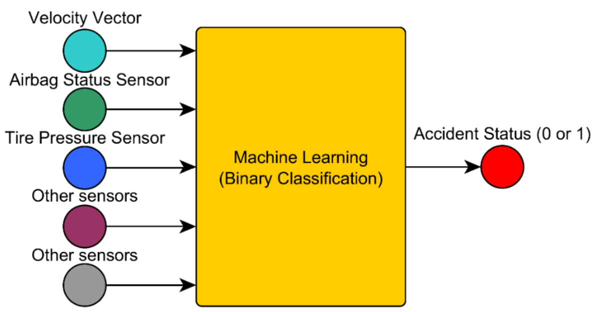


Figure 6. (Generic) Traffic accident status determination process for a smart vehicle. Source: Author's elaboration

At this point, it has to be mentioned that the approach presented above may raise questions regarding the privacy of the vehicle's owners. In order to overcome such allegations, it has to be mentioned that information on longitude and latitude where a potential traffic accident has been identified will only be disclosed when there is a strong indication that an accident has taken place. No other information e.g. identity of people involved in the accident, will be shared. For the coordination of traffic police, fire emergency response services and an integrated approach has to be in place. The longitude and latitude of traffic accidents are disclosed to the closest city[4] that is jurisdictionally responsible for the transportation infrastructure where the traffic accident has taken place.

Figure 7 presents the response flowchart for an identified traffic accident. It incorporates both short-term response actions i.e. dispatching of relevant services; and medium to long-term collection of the 'demographics' of the identified traffic accidents, i.e. all the demographics related to the citizens involved in the accident and projections regarding the impact of the accident on the individuals as well as the society within which they act with respect to productivity and any other quantifiable indicators.

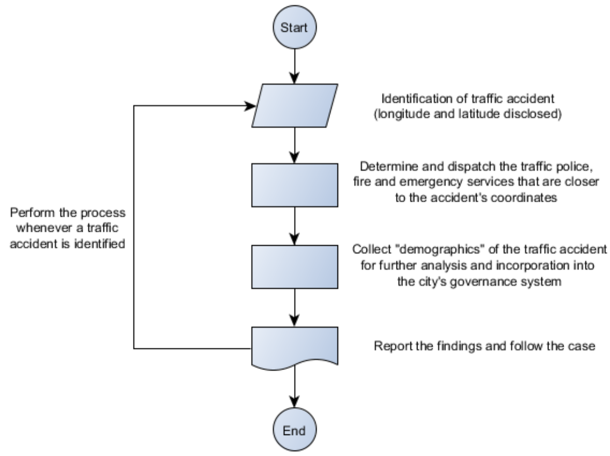


Figure 7. Response flowchart for an identified traffic accident incident in the jurisdictional boundaries of any given city.

Source: Author's elaboration

For the economic and societal implications, the city's economic and social services should develop an integrated plan for monitoring the demographics of traffic accidents. This includes the collection of data for the people involved in the accident, the main reason of the accident, i.e. drunk drivers, misfunction of city's technical infrastructure, sabotage, etc. Projections of economic and productivity losses accounting for the 'profiles' of individuals involved in traffic accidents should be performed by properly trained citizen's officials e.g. statisticians dealing with data analysis and modelling. In this way, the aggregated cost of traffic accidents can be accurately assessed.

Case analysis

The framework proposed in this work can be seen as a constant feedback loop "sensing" what is happening in terms of traffic accidents in cities in order to

4 The closest city in terms of jurisdictional boundaries. For large metropolitan areas, the first (sub-) city to be informed is the one that is jurisdictionally responsible for the transportation infrastructure where the accident has been identified. Neighboring (sub-) cities, close to the accident's coordinates, should be informed as well. The coordinates of the traffic accident can be used as an input for this task aiming at minimizing the response time of relevant services.

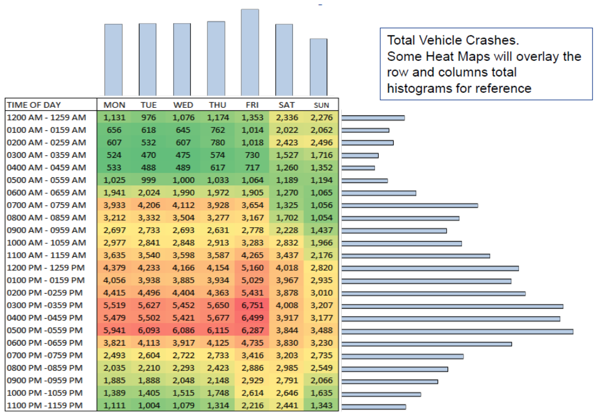
coordinate the organized response from the authorities of a city. The rapid emergence of IoT enabled intelligent components is a prerequisite for the realization of the proposed monitoring and governance system. An increasing number of vehicles, buses, trams, e-bikes, etc. is expected to be equipped with hardware and software that enables IoT technology, and thus to be connected in real-time to the Internet through technologies such as 5G (IEEE, Spectrum). This reality simplifies the process of collection of the data needed for depicting the real-time status and density of traffic accidents in the city of Athens.

Two pillars can be identified, i.e. first; the capacity for the cities' authorities to be informed in real-time for an accident incident and second; the aggregation of accidents incidents in periodic time interval e.g. monthly or yearly aggregations that would be used as input for informed policy making procedures meaning that if in a given area a high density of traffic accident incidents is identified, then the city authorities should identify the factors contributing to this high concentration of accidents and coordinate interventions that would transform the given situation.

With respect to the real-time identification of traffic accidents, the city's authorities should maintain geographic information systems covering their jurisdictional boundaries capable of interoperating with data received through 5G technology operators in order to identify accurately any incident. All the incidents should be stored in geodatabases for further analysis and processing. For supporting informed policy making decisions, exploratory data analyses on the aggregated data can be performed. Netek, R., et al., (2018) suggested the use of visualization tools such as spatiotemporal heatmaps that could instantly clarify the big picture regarding traffic accidents in cities. The gathered insights could then be used for coordinating actions in order to alter the situation. Contemporary developments in machine learning technologies (Ren H., et al, 2018), (Chen C., 2017), (Medium GeoAI, 2018), (freeCodeCamp.org, 2018) could be utilized in order to perform citywide traffic accident risk predictions. Such systems could be part of daily monitoring activities performed by operators of transportation infrastructure systems where the predictions performed by the sophisticated machine learning algorithms could be compared to actual traffic accidents within the jurisdictional boundaries of a city.

Figure 8 presents temporal heatmap statistics for total vehicle crashes during a week. A similar map could be created for all the cities that would deploy a system similar to what is proposed in this work, after relevant historical data is available.

Figure 9 presents the spatial distribution of traffic accidents in a given city. Other sources with similar visualizations can be found in 2000-2010 Traffic Accident Heat Map. ArcGIS (2021) and Road accidents in Greater Manchester 2010. Ondemandmapping.org.uk (2021). Aggregated inputs with data points for traffic accidents across the jurisdictional boundaries of any given city could be used for creating similar heatmaps. Areas with high concentration of traffic accidents should be properly investigated and root-cause relationships should be effectively determined. A roadmap, incorporating potential intervention actions, tools and inputs to be utilized for the alteration of the situation should be established as well.



TIME OF DAY	MON	TUE	WED	THU	FRI	SAT	SUN
1200 AM - 1259 AM	1,131	976	1,076	1,174	1,353	2,336	2,276
0100 AM - 0159 AM	656	618	645	762	1,014	2,022	2,062
0200 AM - 0259 AM	607	532	607	780	1,018	2,423	2,496
0300 AM - 0359 AM	524	470	475	574	730	1,527	1,716
0400 AM - 0459 AM	533	488	489	617	717	1,260	1,352
0500 AM - 0559 AM	1,025	999	1,000	1,033	1,064	1,189	1,194
0600 AM - 0659 AM	1,941	2,024	1,990	1,972	1,905	1,270	1,065
0700 AM - 0759 AM	3,933	4,206	4,112	3,928	3,654	1,325	1,056
0800 AM - 0859 AM	3,212	3,332	3,504	3,277	3,167	1,702	1,054
0900 AM - 0959 AM	2,697	2,733	2,693	2,631	2,778	2,228	1,437
1000 AM - 1059 AM	2,977	2,841	2,848	2,913	3,283	2,832	1,966
1100 AM - 1159 AM	3,635	3,540	3,598	3,587	4,265	3,437	2,176
1200 PM - 1259 PM	4,379	4,233	4,166	4,154	5,160	4,018	2,820
0100 PM - 0159 PM	4,056	3,938	3,885	3,934	5,029	3,967	2,935
0200 PM -0259 PM	4,415	4,496	4,404	4,363	5,431	3,878	3,010
0300 PM -0359 PM	5,519	5,627	5,452	5,650	6,751	4,008	3,207
0400 PM -0459 PM	5,479	5,502	5,421	5,677	6,499	3,917	3,177
0500 PM -0559 PM	5,941	6,093	6,086	6,115	6,287	3,844	3,488
0600 PM -0659 PM	3,821	4,113	3,917	4,125	4,735	3,830	3,230
0700 PM -0759 PM	2,493	2,604	2,722	2,733	3,416	3,203	2,735
0800 PM -0859 PM	2,035	2,210	2,293	2,423	2,886	2,985	2,549
0900 PM -0959 PM	1,885	1,888	2,048	2,148	2,929	2,791	2,066
1000 PM -1059 PM	1,389	1,405	1,515	1,748	2,614	2,646	1,635
1100 PM -1159 PM	1,111	1,004	1,079	1,314	2,216	2,441	1,343

Figure 8. Temporal heatmap statistics for total vehicle crashes. Source: Model Systems Knowledge Translation Centre, (2020).

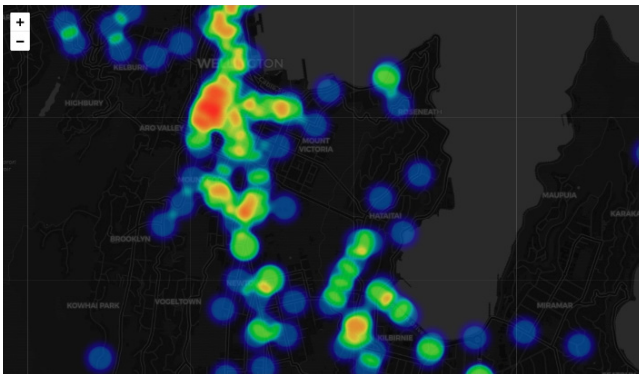


Figure 9. Spatial heatmap of vehicle crashes in a given city.

Source: Towards Data Science, (2019)

Regarding the first pillar, the key question to be answered is "how can the status, i.e. an accident incident can, be captured"? In order to answer to this question a differentiation between the vectors (e.g. velocity, etc.) that characterize the flow of vehicles during normal and abnormal situations has to take place. A combination of inputs such as rate of increase or decrease of velocity, airbag activation, sudden flat tire, etc. could be used for determining whether there is an accident incident or not. These inputs can be provided to a routine running in the central computer supporting and controlling the smart vehicle through IoT enabled sensors spread in different part of the vehicle. When an accident incident is identified then the coordinates (longitude, latitude) of the location should be disclosed to the traffic accidents' monitoring system of the jurisdictionally responsible city. For small cities (including villages and towns) where only one traffic police and fire service exist, on the receipt of such a signal an immediate response procedure is triggered. For larger cities and megacities, the closest police, fire and emergency services should be informed in order to trigger a proper response mechanism. Regarding the second pillar, the aggregation of data for traffic accidents should take place aiming at searching correlations between the quality of the transportation infrastructure and/or climate conditions as well as the condition, i.e. alcohol or drugs use and any other relevant demographics of the accident, of the citizens involved at the time of a traffic accident.

Privacy issues can be raised due to the fact that information regarding longitude and latitude is of private nature. Modern encryption algorithms can be utilized for taking vehicle of the privacy of the citizens involved in accidents. What is of interest for the city authorities, and the citizens as well, is the minimization of the risks for the citizen and associated costs for the overall performance and management of the transportation infrastructure serving the needs of a city. The real longitude and latitude of the incident are exposed only when accident incidents are identified, meaning that a conditioned data sharing mechanism is in place and data are shared with authorities only when emergency situations arise.

Tables 1-2 present the management, policy, and the transition challenges for urban managers and policy makers as identified for the needs of the proposed framework.

Challenges	Infrastructure	Services	Data
Technological	Coverage range of V2I system		Data standardization Data infrastructures
Economic	Financing the V2I system	New business models	Financing of the Data Infrastructure
Social	User acceptance (IoT enabled components in smart vehicles)	Social acceptance (increased cities' responsiveness)	User acceptance (privacy/security issues)
Political	Infrastructure development and planning	Coordination of automotive industry Regulation of competition between manufacturers	Data policies and regulations
Jurisdictional	Infrastructure development and planning	Coordination of vehicles manufactures, and services offered to citizens	Data policies and regulations

Table 1. Management and policy challenges for urban managers (in black) and for policy makers (in red),

Source: Adapted from Finger M. (2020)

	Technological	Financial	Political	Social	Environmental
Services layer	Incorporation of relevant standards Prioritize start-ups or global players	Data pricing schemes Public policy driven or other mechanism?	Data regulation mechanism Privacy and regulation	Data Ownership and Privacy Citizens' adaptation to feedbacks	Life-cycle considerations of IoT components Environmental considerations of digitalization
Data / digital layer	Integration of services City as the platform owner and/or user?	Competition and/or cooperation Enable the development or develop services?	Problem solving criteria for services development Governance of services by citizens	Liability parties Universality of Services provided to citizens	Behavior alteration or optimization? Incentivize the transition towards the emerging infrastructures
Infrastructure layer	Integration of emerging and legacy infrastructure s Use of existing or deployment of new infrastructure ?	Who undertakes infrastructure development costs? Financing of emerging infrastructures	Long-term impact of decisions Infrastructure incorporation into the Smart City Concept	Externalities management Smart and Responsive cities for the benefit of citizens	Life-cycle considerations of IoT components Decentralized platforms at the (sub-) city level

Table 2. Transition challenges for urban managers (in black) and for policy makers (in red),

Source: Adapted from Finger M. (2020)

Conclusion

In this work, traffic problems in Athens were discussed, and a framework for the real-time identification of traffic accidents in cities was presented. The added value of the work lies on the fact that it advocates the use of contemporary developments in a number of fields, including IoT enabled smart vehicles, next generation telecommunication infrastructure, i.e. 5G, and machine learning algorithms for the identification of accidents in real-time and instantaneous disclosure of the coordinates of the accident to the jurisdictionally responsible city in order to foster smart, fast and accurate response of the relevant services so as to minimize human capital loss and negative economic impact due to unavailability of part of the transportation infrastructure of a given city. The realization of the real-time monitoring of traffic accidents has as prerequisite the presence of a Geographic Information System (GIS) map covering the jurisdictional boundaries of a city that is capable of receiving traffic accident signals in real-time. After properly responding to the emergency, the city's authorities should monitor the 'demographics' of the accident in order to determine the economic impact of the accidents on the functioning of the city. Aggregated data could be used for the supporting evidence-based policy making processes at the city level in order to coordinate intervention strategies when needed. It has to be mentioned that the proposed framework can only act as an 'intermediate stage' between the current stage regarding the automation of vehicles and a fully automated future where no traffic accidents are anticipated due to the presence of the collective intelligence and coordinated cooperation of IoT enabled and AI supported smart vehicles. Existing and emerging IoT components could be used as a cheap solution to transform the current vehicle fleet to be capable of determining the accident status of a vehicle and properly disclosing the coordinates of the vehicle when an accident is identified. The implementation of the proposed framework could increase the responsiveness of city's authorities with respect to traffic accidents and boost citizens' awareness in areas with high concentrations of accidents while being a fundamental precondition for coordinating informed interventions from local, regional and national policy making bodies. The introduction of the approach presented in this work into the IT systems deployed and utilized by the city of Athens. It would enhance the capacity of city's authorities to identify traffic accidents and increase its responsiveness for dealing with the negative consequences of traffic accidents both in the short-term, e.g. congestions in different parts of the transportation infrastructure, and in long-term affecting the productivity of whole regions e.g. when a high number of traffic accidents is presents leading to injuries and fatalities of the citizens residing in the region of Attica where Athens is based.

Appendix

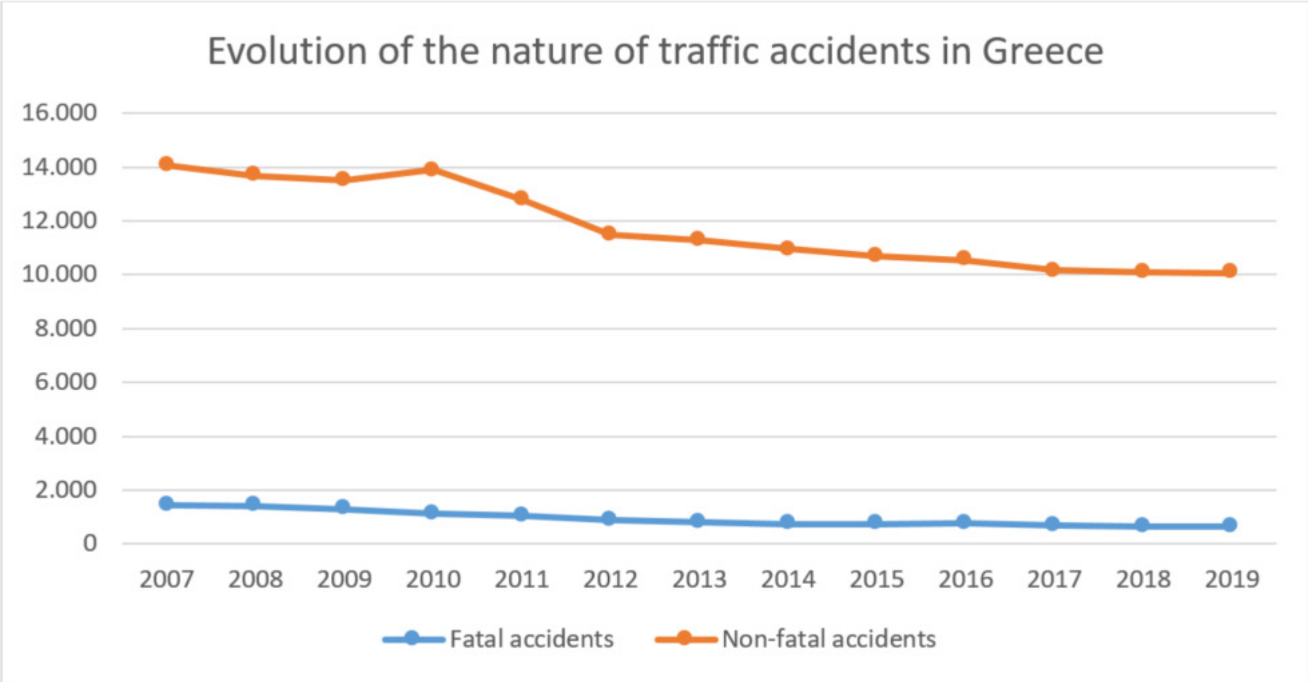


Figure S1. Evolution of the nature of traffic accidents in Greece

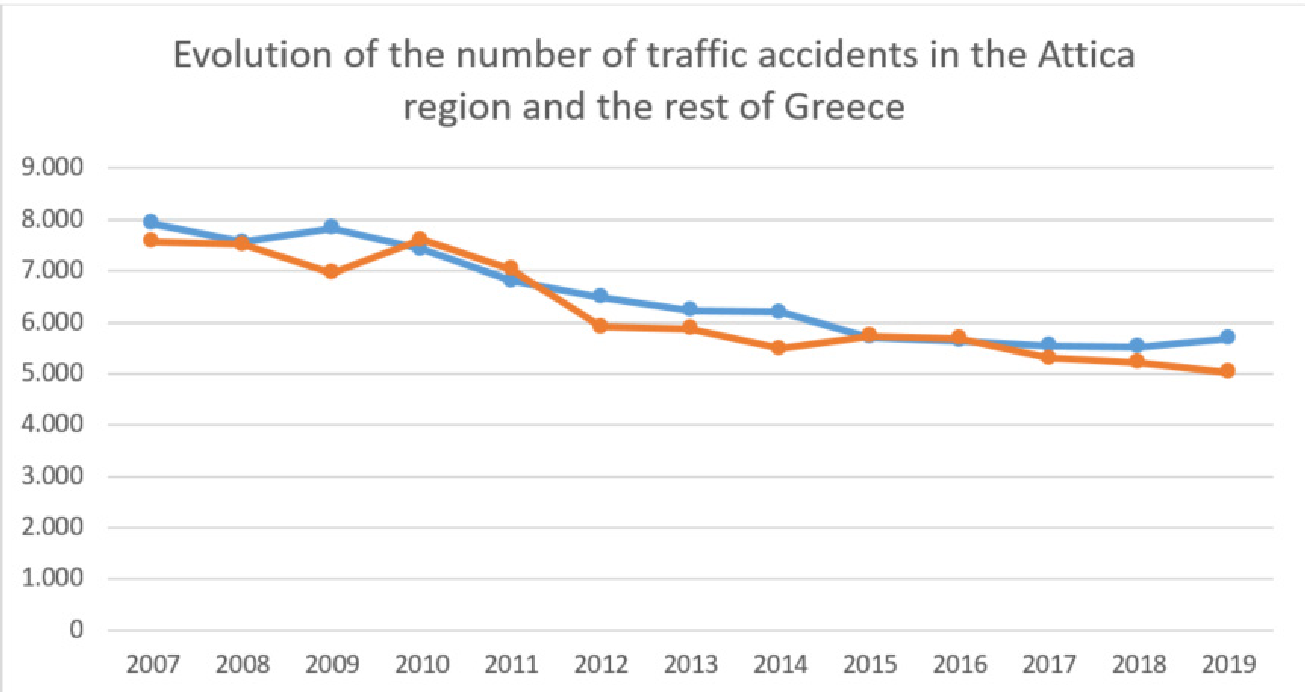


Figure S2. Evolution of the number of traffic accidents in Attica region and rest of Greece

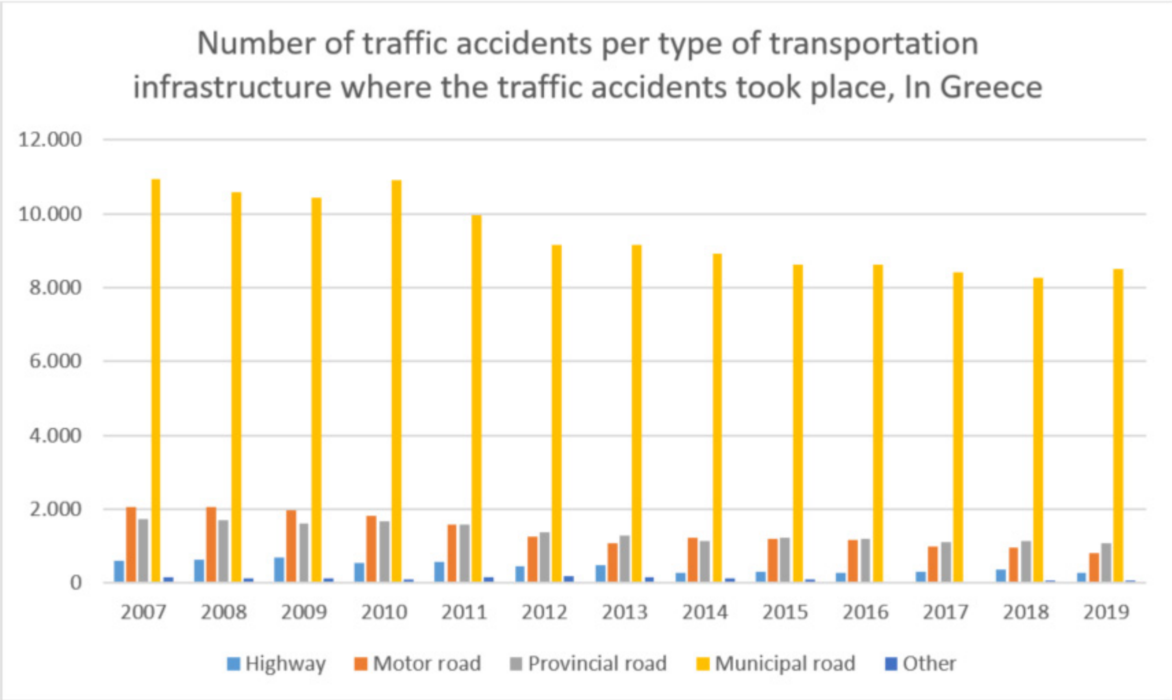


Figure S3. Number of accidents per type of transportation infrastructure where the traffic accidents took place

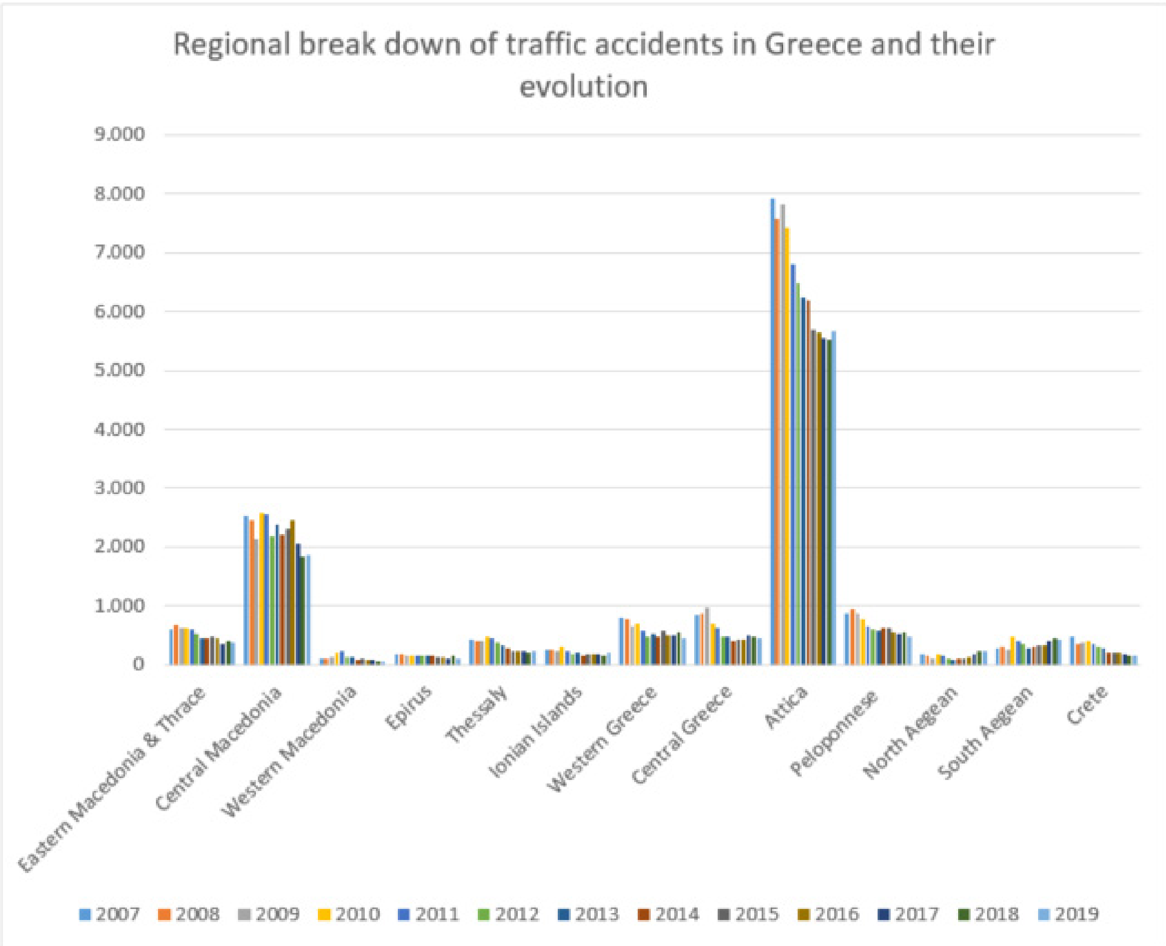


Figure S4. Evolution of traffic accidents, broken down by the region of occurrence, in Greece

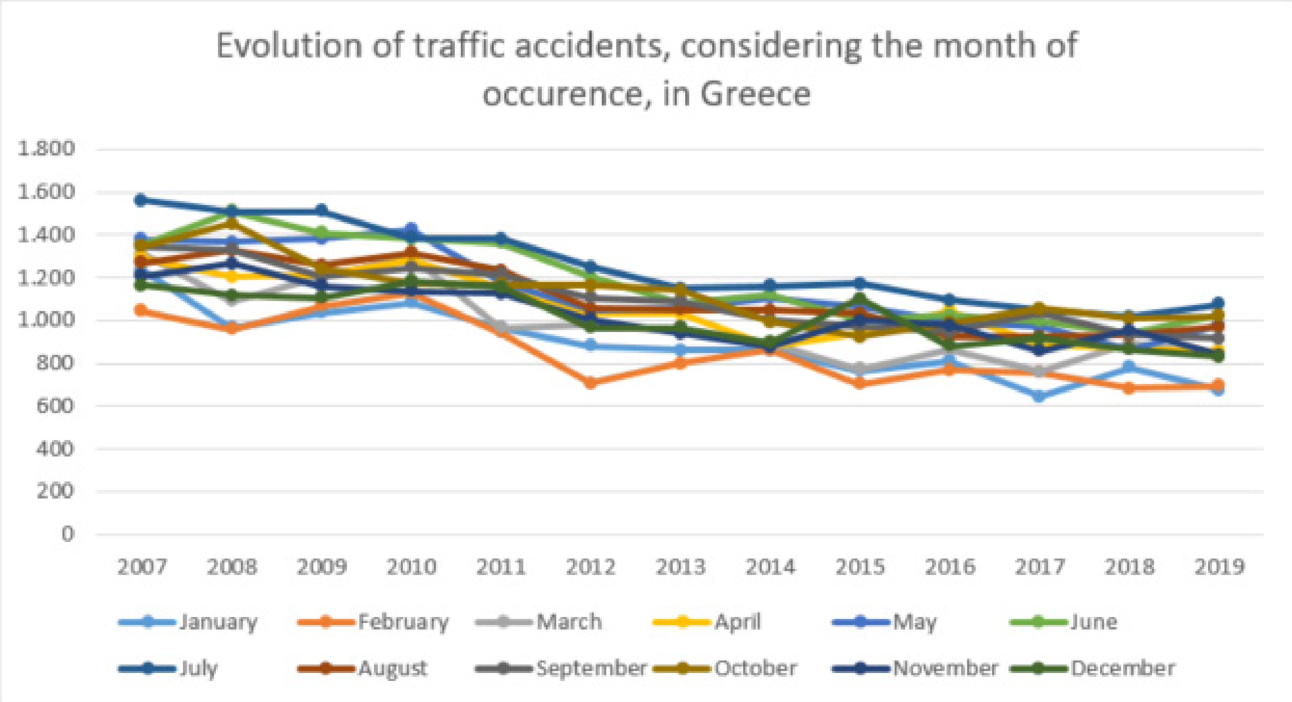


Figure S5. Evolution of traffic accidents, considering the month of occurrence, in Greece

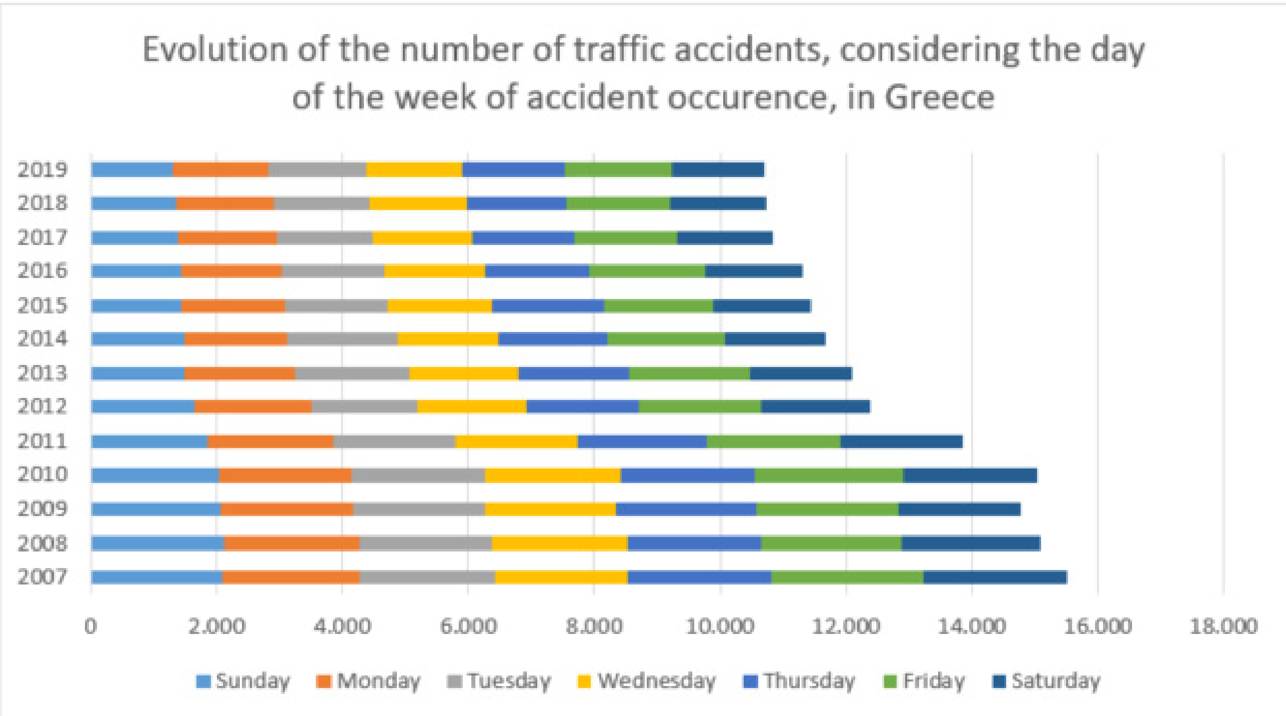


Figure S6. Evolution of the number of traffic accidents, considering the day of the week of accident occurrence, in Greece

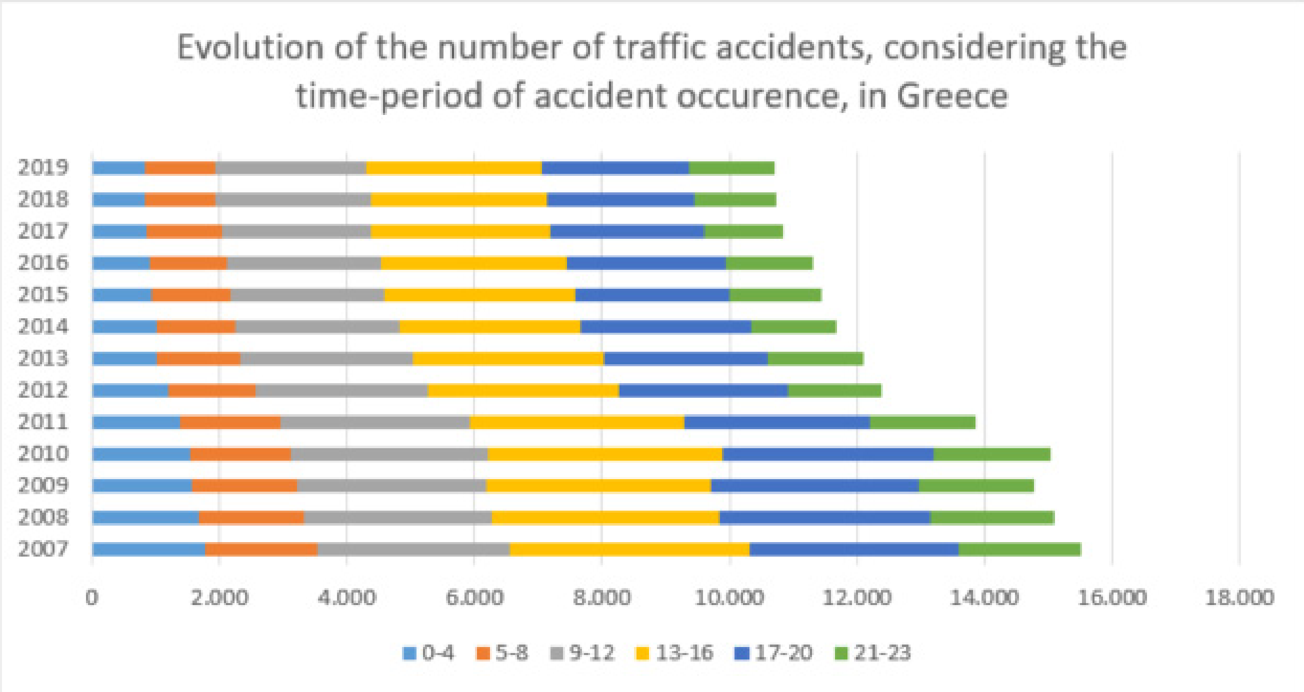


Figure S7. Evolution of the number of traffic accidents, considering the time-period of accident occurrence, in Greece

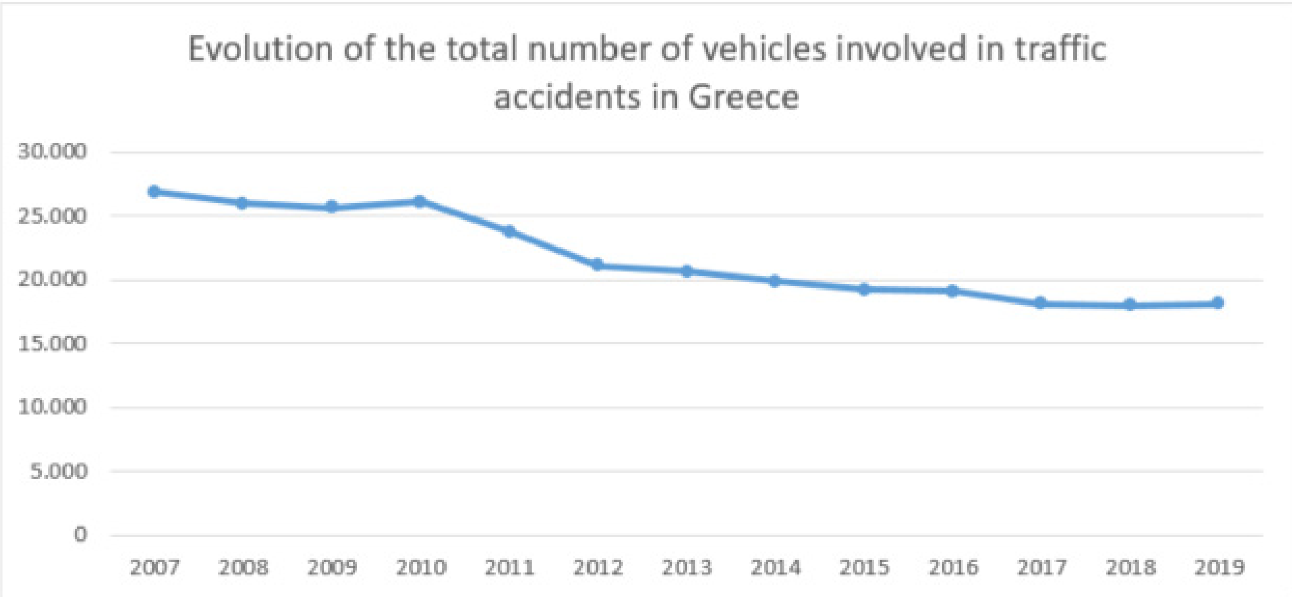


Figure S8. Evolution of the total number of vehicles involved in traffic accidents in Greece

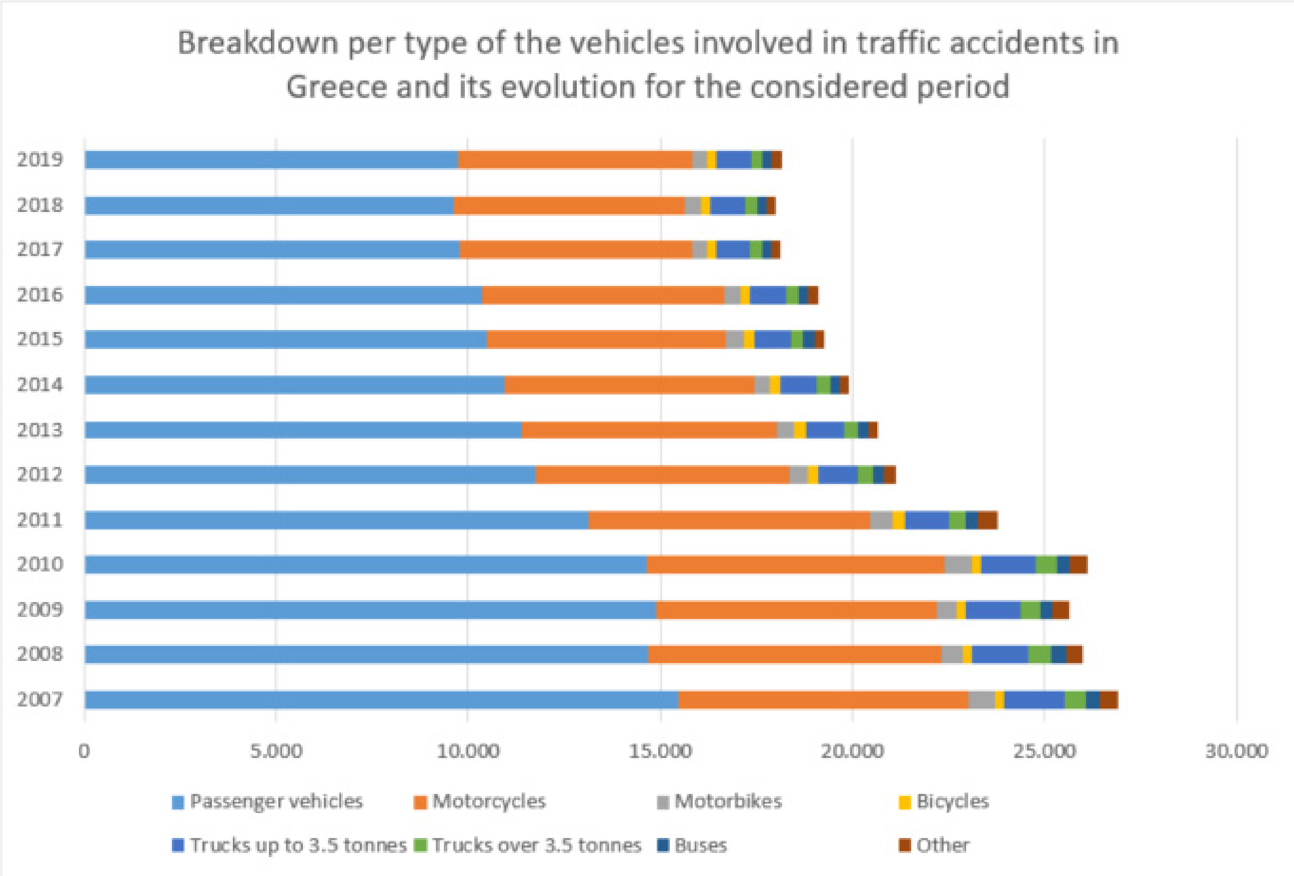


Figure S9. Breakdown per type of the vehicles involved in traffic accidents in Greece and its evolution for the considered period

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Announcements

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IGLUS Quarterly is an analytical open access journal dedicated to the analysis of Governance, Innovation and Performance in Cities and is edited at EPFL ME, Ras Al Khaimah, U.A.E. IGLUS Quarterly aims to facilitate knowledge and experience sharing among scholars and practitioners who are interested in the improvement of urban system's performance in terms of the service efficiency, sustainability and resilience.

IGLUS Quarterly applies the highest academic standards to analyze real world initiatives that are dealing with today's urban challenges. It bridges the gap between practitioners and scholars. IGLUS Quarterly therefore adopts a multidisciplinary perspective, simultaneously considering political, economic, social and technological dimensions of urban systems, and with a special focus on how governance affects and is affected by the use of technologies in general, and especially the pervasive application of the ICTs.

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