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Characterization of Road Crashes in the Emirate of Abu Dhabi

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Abstract

Road crashes have historically plagued the Gulf Cooperation Council (GCC) countries. Unfortunately, vehicle crash studies conducted in the GCC region have been scarce, making it difficult for decision-makers and researchers to assess the magnitude of the road safety problem regionally and to tackle it effectively. In the present study, the authors investigate the contributing factors to increased road crash severity based on collisions having occurred between 2012 and 2017 in the Emirate of Abu Dhabi, part of the United Arab Emirates (UAE). This study may be relevant not only to the UAE, but also to other GCC countries due to their similarities in road design, vehicle fleet, and driving culture. The study finds that 1.26 million crashes, 9,327 injuries, and 1,305 fatalities occurred during the period covered. Road crashes were more likely to produce severe and fatal injuries when collisions occurred between 22:00 and 5:59 o'clock, occurred under adverse weather conditions, involved pedestrians or drunk drivers, occurred on higher-speed-limit highways, as well as when drivers were male, minors, and/or Emiratis. UAE nationals were found to be very overrepresented both in terms of the total number of crashes and number of severe/fatal crashes. In addition, tailgating and reckless driving were the main reasons for crashes in an overwhelming 50 percent of the incidents. Finally, more than half of all injured people were not wearing a seat belt. Finally, the authors provide data-driven recommendations to improve road safety in the Emirate of Abu Dhabi.

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Keywords: Road Crashes, Crash Severity, Contributing Factors, Abu Dhabi Emirate

1. Introduction

1.1 Background

Over 1.2 million lives are lost and over 50 million injuries are sustained annually due to road crashes worldwide. In addition, 90 percent of these casualties occur in countries outside the developed world while these nations generate only 40 percent of all motorized trips [1]. Globally, the estimated economic toll produced by road crashes is estimated to be circa US$ 500 billion. Indeed, the economic burden produced by road crashes has been estimated to be between 1 and 3 percent of the gross national product (GNP) of a significant number of countries worldwide [2]. Generally, the lower a country's GNP (i.e., the poorer the country), the higher the economic burden produced by road crashes,

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on a percentage basis. Hence, these numbers indicate that third-world and developing countries desperately demand the implementation of effective and economically feasible road safety countermeasures.

The Gulf Cooperation Council (GCC) region has been especially impacted by the excessive number of road crashes and injuries [3-10]. The United Arab Emirates (UAE), in particular, has shown declining road-injury and fatality records; yet, road crashes continue to take an economic toll on the country [11]. Statistics reveal that Gulf countries including Saudi Arabia, Qatar, Kuwait, UAE, Oman, and Bahrain, continue to struggle with road safety problems [3-11]. Unfortunately, the number of detailed, publicly available vehicle crash studies conducted in the GCC region has historically been scarce, making it difficult for researchers to assess the road safety problem, identify key research needs, and develop effective road safety solutions for the GCC region. Hence, there is a need to not only understand the causes and consequences of crash events, but also to disseminate this knowledge in the form of publicly available information.

1.2 Objectives

The main objective of this study was to identify the contributing factors to increased road crash severity in the Emirate of Abu Dhabi. Some of the questions this study may help answer are: when, how, where, and to whom do more severe crashes tend to happen to?

1.3 Study Relevance

The findings of this study should be relevant not only to the UAE, but also to other GCC countries (i.e., Bahrain, Kuwait, Oman, Qatar, and Saudi Arabia) whose road design, as well as traffic characteristics and driving cultures, may be similar. The findings of this research may also be relevant to government authorities, traffic law enforcement representatives, researchers, and practitioners.

2. Methods

The present study was heavily based on road crash data collection and analysis. The next three sub-sections provide information on: the study area under consideration, the crash data collection process, and the crash data analysis techniques used.

2.1 Study Area

The study area covered was the entire Emirate of Abu Dhabi, which is the largest Emirate in the UAE, accounting for 87 percent of the UAE's land mass, as shown in Figure 1. The Emirate of Abu Dhabi has a total area of approximately 67,340 km^2, has a road network of over 21,000 kilometers, and is home to over 2.9 million inhabitants. There are over 1 million registered drivers and 1 million registered vehicles in the Emirate of Abu Dhabi [12, 13].

Figure 1. The Seven Emirates Forming the United Arab Emirates

2.2 Data Collection

Almost six years' (i.e., 2012 to 2017) worth of vehicle crash data was collected from the Abu Dhabi Traffic Police database. Unfortunately, crash data referring to December 2017 could not be included. Two databases were provided by Abu Dhabi Traffic Police. One dataset contained records on all non-injury crashes, while the other dataset contained records on all injury crashes. The injury dataset was more comprehensive, as it included a few variables which were not made available in the non-injury database. Table 1 shows the variables which were used in this study, and whether they were available in the injury dataset only or in both the injury and non-injury datasets.

Table 1. Crash Data Variables and Database Sources

Database	Variable	Related To	Can Help Answer	See Table
Non-Injury and Injury	Calendar Year	Time	When do more severe crashes happen?	NA
	Month			NA
	Day of the Week			NA
	Time of the Day			1
	Crash Severity	Crash	What are the crash consequences?	All
	Weather Type		Under which conditions do more severe crashes happen?	4
	Crash Type		How do more severe crashes happen?	5
	Reason for Crash		Why do more severe crashes happen?	6
	Posted Speed Limit	Road	Where do more severe crashes happen?	7
Injury	Lighting Condition		Where and under which conditions do more severe crashes happen?	8
	Seat Belt Use Status of Injured Person	Vehicle Occupant	Who is more likely to be involved in more severe crashes?	9
	Seating Position of Injured Occupant			NA
Non-Injury and Injury	Driver at Fault's Gender			10
	Driver at Fault's Age			11
	Driver at Fault's Physical Condition			12
	Driver at Fault's Nationality			NA

2.3 Data Analysis

A number of distributions were tabulated showing how crash severity is distributed in relation to a number of relevant time-, crash-, road-, and vehicle-occupant-related variables. Crash severity was classified into 3 levels: "non-injury", "not severe", and "severe". Injuries reported as "minor" or "moderate" were combined in the "not severe" category, while injuries reported as "disabling" or "fatal" were combined in the "severe" category. Bivariate analyses using cross tabulation were carried out by calculating row and column percent values. That is, under each column category, the left-most percent values refer to the percent values across the columns while the right-most percent values refer to the percent values across the rows.

3. Results

3.1 Time-Related Characteristics

It was found that 1.26 million crashes, 9,327 injuries, and 1,305 fatalities occurred during the period covered. Thus, less than 1 percent of all crashes produced injuries. The total number of annual crashes grew from 188,154 in 2012 to 232,326 in 2016. The total number of crashes in 2017 was 181,991, but crash data from December 2017 was not collected. Thus, while the total number of crashes followed an upward trend over the years, the number of minor and severe injury crashes significantly decreased, while the number of moderate and fatal injury crashes remained flat, as shown in Figure 2. The most important takeaway from this is that the number of injury crashes decreased (i.e., from 1,992 in 2012 to 1,697 in 2016), while total number of crashes, population, number of registered vehicles, and number of registered drivers have all experienced growth [14, 15].

In regards to other temporal characteristics, the number of crashes by month varied from approximately 95,000 to 120,000, with the months of May and June accounting for the highest percent of annual crashes, 9.4 and 9.0 percent, respectively. On the other hand, the months of November and December accounted for the lowest number of crashes, with both accounting for less than 8 percent of the annual crashes.

It was also found that the number of crashes that occurred on weekdays was higher as compared to weekends (i.e., Friday and Saturday). While weekdays accounted for between 15 and 16 percent of the weekly number of crashes, Fridays accounted for 8 percent and Saturdays for 12 percent. This difference in crash frequency between weekdays and weekend days may be explained by the higher traffic volumes on weekdays. However, a striking difference in the risk of an injury occurrence on Fridays relative to weekdays was found. That is, for instance, it was found that 0.17 percent of all Friday crashes resulted in fatalities. On the other hand, it was found that 0.09 percent of all Sunday crashes resulted in fatalities. Even though the difference (i.e., 0.08) between these two proportions may seem small, the sample relative risk is found to be 1.88 (i.e., 0.17 divided by 0.09), which means that the sample proportion of fatal cases was 88 percent higher for the Friday sample as compared to the Sunday sample.

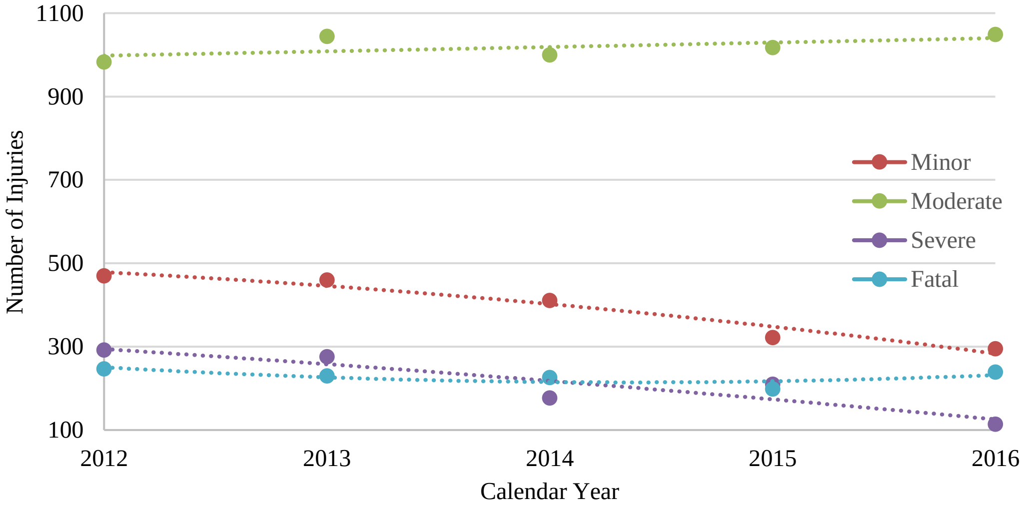

Figure 2. Number of Injuries by Severity and Calendar Year

Over 80 percent of all crashes happened between 6:00 and 21:59 o'clock, with the highest number of crashes occurring between 12:00 and 14:00 o'clock. This may be explained by the fact that traffic volumes tend to be higher during those time windows. Table 2 also shows that while only 15.36 percent (see cell in green) of all crashes occurred between 22:00 and 5:59 o'clock, 24.81 percent of all minor/moderate crashes and 26.46 percent (see cells in blue) of all severe/fatal crashes occurred within that same time interval.

Alternatively, Table 2 also indicates that 0.34 percent (see cell in yellow) of all crashes that occurred between 22:00 and 5:59 o'clock involved severe/fatal crashes, while only 0.17 percent (see cells in orange) of all crashes occurring at any other time involved severe/fatal injuries. This implies that crashes occurring between 22:00 and 5:59 o'clock are more likely to produce severe injuries.

Again, in terms of relative risk, the sample relative risk is found to be 2 (i.e., 0.34 divided by 0.17), which means that the sample proportion of fatal/severe cases was 100 percent higher for the late-hour-crash sample. This may be due to the combination of a number of factors such as higher traveling speeds due to lower traffic volumes during the time between 22:00 and 5:59 o'clock, as well as increased driver fatigue and, perhaps, less law enforcement and more reckless behaviour influenced by drunk driving.

Table 2. Crash Severity Distribution by Time of Day

			Time of Day						Row-Totals	
			22:00 - 05:59		06:00 - 13:59		14:00 - 21:59		#	%
Crash Severity	No Injury	#	191,972		538,018		526,565		1,256,555	99.16
		%	98.62	15.28	99.28	42.82	99.24	41.91		
	Minor/Moderate	#	2,018		2,999		3,117		8,134	0.64
		%	1.04	24.81	0.55	36.87	0.59	38.32		
	Severe/Fatal	#	661		921		916		2,498	0.20
		%	0.34	26.46	0.17	36.87	0.17	36.67		
	Column-Totals	#	194,651		541,938		530,598			
		%	15.36		42.77		41.87			

3.2 Crash-Related Characteristics

Table 3 shows the crash severity distribution by weather type. As can be seen, 99.04 percent (see cell in green) of all crashes occurred under clear weather conditions, which is not surprising since this is the most often-occurring weather condition in the GCC region.

Table 3 also indicates that while foggy/dusty weather conditions accounted for only 0.31 percent (see cell in blue) of all crashes, 2 percent (see cell in yellow) of all severe/fatal crashes occurred under this weather type. Severe/fatal crashes were also found to be overrepresented under rainy/stormy weather conditions. That is, while only 0.61 percent (see cell in orange) of the crashes occurred under rainy/stormy weather conditions, 1.92 percent (see cell in gray) of all severe/fatal crashes occurred under rainy/stormy weather conditions.

Alternatively, Table 3 also indicates that out of all crashes having occurred under clear weather conditions, only 0.19 percent (see cell in purple) of them resulted in severe/fatal injuries. On the other hand, out of all crashes that occurred under foggy/dusty weather conditions as well as out of all crashes that occurred under rainy/stormy weather conditions, 1.25 and 0.62 percent (see cells in brown) resulted in severe/fatal injuries. Hence, no matter how one looks at these distributions, it is clear that adverse weather conditions significantly impacted crash severity levels.

These numbers suggest that even though the UAE may generally enjoy driver-friendly weather, increased focus must be devoted to safety measures capable of mitigating the risks associated with being on the road under adverse weather conditions, such as foggy or dusty weather. This might imply, for instance, deploying technology capable of warning drivers about reduced visibility and suggested traveling speeds. In addition, variable posted speed limits may be recommended.

Table 3. Crash Severity Distribution by Weather Type

			Weather								Row-Totals	
			Clear		Foggy/Dusty		Rainy/Stormy		Unknown		#	%
Crash Severity	No Injury	#	1,244,887		3,808		7,529		331		1,256,555	99.16
		%	99.19	99.07	95.51	0.30	97.32	0.60	79.57	0.03		
	Minor/Moderate	#	7,776		129		159		70		8,134	0.64
		%	0.62	95.60	3.24	1.59	2.06	1.95	16.83	0.86		
	Severe/Fatal	#	2,385		50		48		15		2,498	0.20
		%	0.19	95.48	1.25	2.00	0.62	1.92	3.61	0.60		
	Column-Totals	#	1,255,048		3,987		7,736		416			
		%	99.04		0.31		0.61		0.03			

Table 4 shows the crash severity distribution by crash type. It indicates that side-impact and rear-end collisions accounted for just over 57 percent (see cells in green) of all crash types. A significant number of the side-impact collisions most likely occurred at intersections while a significant number of the rear-end collisions most likely occurred due to tailgating (see Table 5). However, these assumptions would require further investigation.

Table 4 also indicates that run-over collisions are by far the most severe casualties. That is, while only 0.2 percent (see cell in yellow) of all crashes resulted in severe/fatal injuries, 19.22 percent (see cell in orange) of all run-over crashes resulted in severe/fatal injuries. In addition, while at least 98 percent (see cells in gray) of any other crash type resulted in no injuries, only a third (see cell in red) of all pedestrian-related crashes did not produce injuries. Hence, vulnerable road users such as pedestrians are grossly overrepresented in the injury data, revealing the vulnerability of pedestrians in regards to suffering injuries in the Abu Dhabi road network. Fortunately, run-over collisions accounted for less than a quarter percent (see cell in blue) of all crashes.

Table 4. Crash Severity Distribution by Crash Type

			Crash Type										Row-Totals	
			Side- Impact		Rear-End		Run-Off-Road		Run-Over		Other		#	%
Crash Severity	No Injury	#	405,751		313,578		118,732		901		417,593		1,256,555	99.16
		%	99.63	32.29	99.39	24.96	99.44	9.45	31.09	0.07	98.92	33.23		
	Minor/Moderate	#	1,178		1,513		495		1,440		3,508		8,134	0.64
		%	0.29	14.48	0.48	18.60	0.41	6.09	49.69	17.70	0.83	43.13		
	Severe/Fatal	#	335		397		168		557		1,041		2,498	0.20
		%	0.08	13.41	0.13	15.89	0.14	6.73	19.22	22.30	0.25	41.67		
	Column-Totals	#	407,264		315,488		119,395		2,898		422,142			
		%	32.14		24.90		9.42		0.23		33.31			

Table 5 shows the crash severity distribution by main reason for crash. There were an extensive number of reasons for crashes listed in the database, making it impractical to list all of them. Furthermore, most of the listed reasons accounted for a relatively insignificant number of crashes. Thus, only a handful of main reasons for crashes are listed in Table 5. This is why if percentages in the green cells are added to percentages in the brown cells, they do not add up to 100.

Table 5 shows that almost 74 percent (see cells in green) of all crashes were considered to be the result of tailgating, reversing, and reckless driving behavior. However, on a percentage basis, red light running and drunk driving were the reasons associated with more severe/fatal crashes. That is, while at least 99 percent (see cells in blue) of all crashes associated with tailgating, reversing, and reckless behavior resulted in no injury, only approximately 80 percent (see cells in yellow) of all crashes associated with red light running and drunk driving resulted in no injuries. In addition, while only 0.07 percent of all crashes caused by tailgating, 0.01 percent of all crashes caused by reversing movements, and 0.18 percent of all crashes caused by reckless behavior resulted in severe/fatal injuries (see cells in orange), strikingly, 2.51 percent of all crashes caused by red light running and 2.45 percent of all crashes caused by drunk driving resulted in severe/fatal injuries (see cells in red). Even more striking numbers (see cells in gray) can be observed if the same reasoning is applied to the minor/moderate injury category. These are very insightful figures suggesting that:

i) Tailgating and reckless driving might be often practiced.
ii) Collisions while reversing are almost always injury-free events, probably due to the low speeds involved. However, these collisions accounted for almost one-quarter of all crashes. Hence, this may indicate that drivers may need to be better educated on the rules regarding yielding practices when vehicles are backing up (i.e., especially from parking bays onto the roadway).

Even though the combined number of crashes caused by red light running and drunk driving accounted for only 0.51 percent (see cells in brown) of all crashes, they accounted for a disproportional 6.44 percent (see cells in purple) of all severe/fatal crashes and a very striking 14.33 percent (see cells in pink) of all minor/moderate crashes. These numbers suggest that intersection operations and design, as well as enforcement practices may need to be revised. Perhaps, this may be an indication that other intersection design types may need to be considered, such as roundabouts, in order to improve safety. This, however, may need to be the subject of further research. Lastly, even though drunk driving may not be a common cause for crashes in Abu Dhabi, probably due to cultural objection to alcohol consumption by a large part of the population, Table 5 shows how much more injury-crash-prone people may be when impaired drivers are behind the wheel. Hence, a greater focus on tackling impaired driving may need to be put into place, which may mean first identifying where and when law enforcement is most likely to catch motorists under the influence of alcohol.

Table 5. Crash Severity Distribution by Reason for Crash

			Main Reason for Crash										Row-Totals	
			Tailgating		Reversing		Reckless Driving		Red Light Running		Drunk Driving		#	%
Crash Severity	No Injury	#	323,828		307,828		301,203		3,206		1,929		1,256,555	99.16
		%	99.60	25.77	99.96	24.50	99.26	23.97	78.27	0.26	81.56	0.15		
	Minor/Moderate	#	1,086		98		1,696		787		378		8,134	0.64
		%	0.33	13.35	0.03	1.20	0.56	20.85	19.21	9.68	15.98	4.65		
	Severe/Fatal	#	218		31		537		103		58		2,498	0.20
		%	0.07	8.73	0.01	1.24	0.18	21.50	2.51	4.12	2.45	2.32		
	Column-Totals	#	325,132		307,957		303,436		4,096		2,365			
		%	25.66		24.30		23.95		0.32		0.19			

3.3 Road-Related Characteristics

Table 6 shows the crash severity distribution by posted speed limit. It is worth noting first that, until recently, drivers in the Emirate of Abu Dhabi were legally allowed to drive 20 kph above the posted speed limit before they were fined for speeding. The Emirate of Abu Dhabi has recently eliminated this speed buffer and raised the posted speed limit by 20 kph [16-17]. As can be seen from Table 6, only 0.04 and 0.29 percent (see cells in green) of all crashes that occurred on roads with posted speed limits of up to 40 kph and 60-80 kph, respectively, resulted in severe/fatal injuries. On the other hand, 1.51 and 1.50 percent (see cells in blue) of all crashes that occurred on roads with posted speed limits of 100-120 and higher than 120 kph, respectively, resulted in severe/fatal injuries.

It can also be observed that while 65.17 percent (see cell in yellow) of all crashes occurred on roads with posted speed limits of up to 40 kph, only 14.33 percent (see cell in orange) of all severe/fatal crashes occurred on such roads. Conversely, while only 5.45 percent (see cell in gray) of all crashes occurred on roads with posted speed limits of 100-120 kph, a disproportional 41.71 percent (see cell in brown) of all severe/fatal crashes occurred on such roads. These are striking differences that signal the importance of greater design and law enforcement focus on roads with higher posted speed limits, as these roads accounted for a disproportional amount of severe/fatal crashes. The same reasoning can be applied to the "> 120" posted-speed-limit category (see cells in purple).

Lastly, distributions in Table 6 also indicates that while the percentages of severe/fatal crashes are nearly the same for "100-120" and "> 120" posted-speed-limit categories (see cells in blue), the percentage of minor/moderate crashes under the "100-120" is almost double that of minor/moderate crashes under the ">120" category (see cells in pink). This is intriguing as one could expect that the higher the posted speed limit, the higher the percentage of these crashes. While Table 6 shows that this intuitive upward trend holds true for posted speed limits up to the "100-120" category, the trend does not hold true from the "100-120" (i.e., 3.13 percent) to the "> 120" (i.e., 1.63 percent) posted-speed-limit category. This may also need further investigation in order to determine why this is the case, but one could speculate that this could be due to lower design/safety standards on roads under the "100-120" as compared to those applied to roads under the "> 120" posted-speed-limit category. In other words, even though one could be traveling at lower speeds, he/she could still be bearing a larger injury risk on lower-posted-speed-limit roads due to lower design/safety standards.

Table 6. Crash Severity Distribution by Posted Speed Limit

			Posted Speed Limit (kph)								Row-Totals	
			≤ 40		60 - 80		100 - 120		> 120		#	%
Crash Severity	No Injury	#	823,792		365,372		65,843		1,548		1,256,555	99.16
		%	99.75	65.56	98.57	29.08	95.36	5.24	96.87	0.12		
	Minor/Moderate	#	1,720		4,228		2,160		26		8,134	0.64
		%	0.21	21.15	1.14	51.98	3.13	26.56	1.63	0.32		
	Severe/Fatal	#	358		1,074		1,042		24		2,498	0.20
		%	0.04	14.33	0.29	42.99	1.51	41.71	1.50	0.96		
	Column-Totals	#	825,870		370,674		69,045		1,598			
		%	65.17		29.25		5.45		0.13			

Table 7 shows the crash severity distribution by lighting condition. It can be seen that 57.16 percent (see cell in green) of all crashes occurred during daylight, while most night-time crashes occurred at locations considered to have adequate lighting coverage (see cell in yellow). This must not be seen as an indication that night time crashes are more likely to occur at locations with adequate lighting provision but, rather, it must be due to the fact that the majority of the roads in the Emirate of Abu Dhabi do have adequate lighting provision. However, Table 7 does suggest that crash severity tends to be higher on roads with poor or no lighting provision as compared both to crashes that occurred during the daytime, as well as to crashes that occurred during the night time on roads with adequate lighting condition (see cells in blue). That is, out of all night time crashes that occurred on roads with poor or no lighting provision, 34.04 percent resulted in severe/fatal injuries, while out of all night time crashes that occurred on roads with adequate lighting, only 22.46 percent resulted in severe/fatal injuries. This is an interesting finding considering that:

i) Higher-speed roads in Abu Dhabi tend to always be lit.
ii) Higher safety and design standards tend to be applied to higher-speed roads as compared to lower-speed roads.
iii) Finally, if higher-speed roads are more likely to be lit and associated with higher crash severity (see Table 6), then one could speculate that cells in blue shown in Table 7 suggest that lighting may be having a positive effect on crash severity reduction on lower-speed roads.

Table 7. Crash Severity Distribution by Lighting Condition

			Lightning Condition						Row-Totals	
			Daylight		Night: Poor or No Lighting		Night: Adequate Lighting		#	%
Crash Severity	Minor/Moderate	#	4,688		498		2,945		8,131	76.50
		%	77.16	57.66	65.96	6.12	77.54	36.22		
	Severe/Fatal	#	1,388		257		853		2,498	23.50
		%	22.84	55.56	34.04	10.29	22.46	34.15		
	Column-Totals	#	6,076		755		3,798			
		%	57.16		7.10		35.73			

3.4 Vehicle-Occupant-Related Characteristics

Table 8 shows the crash severity distribution by seat belt usage. This data was available for injury crashes only, and it provides information on whether the injured person, who could be the driver or another passenger, was wearing a seat belt when the crash occurred. Table 8 shows that less than half (see cell in green) of all injured people were wearing a seat belt. This suggests that the seat belt usage rate in the Abu Dhabi Emirate may be dangerously low.

Table 8 also shows that out of all vehicle occupants who did not wear a seat belt, 24.33 percent suffered severe/fatal injuries. Similarly, Table 8 shows that out of all vehicle occupants who did wear a seat belt, 21.30 percent suffered severe/fatal injuries (see cells in yellow). Thus, there was no significant difference in injury outcome between the two seat belt usage categories. The difference in the percentage of minor/moderate injuries for each seat belt usage category was also found to be insignificant (see cells in gray). However, these numbers neither necessarily suggest that the chance of suffering severe/fatal injuries is the basically the same whether one is wearing a seat belt or not, nor that half of all the vehicle occupants in the Emirate do not wear seat belts. One needs to consider the following:

i) Because this distribution is based on injury data only, unbelted people would be more prone to be in this crash sample.
ii) In most cases, it is difficult to discern whether someone was wearing a seat belt or not for certain. The most reliable data in this regard would probably be that from fatal crashes only which is not shown in Table 8. However, only 42.53 percent of all fatally injured passengers were found to be wearing a seat belt, which is still an awfully low number.
iii) Finally, this is a bivariate analysis and is not taking into consideration other factors which could potentially also affect the crash severity outcome, such as impact speed, vehicle class, crash type, and posted speed limit. That is, for instance, two crash observations with similar driver profile, weather condition, crash type, and vehicle class result in different crash severity outcomes. One driver suffered minor injuries while not wearing a seat belt and traveling at 40 kph, while the other driver suffered severe injuries while wearing a seat belt and traveling at 80 kph. Hence, this simple example illustrates why one cannot draw meaningful conclusions regarding percentages in the yellow and gray cells. If insightful information is to be drawn from the impact of seat belt usage and crash severity, one needs to make use of statistical techniques capable of controlling for multiple factors simultaneously. Nevertheless, Table 8 provides useful information in regards to seat belt usage in the most severe crash events, which was found to be subpar.

Table 8. Crash Severity Distribution by Seat Belt Usage of Injured Person

			Seat Belt						Row-Totals	
			Not Used		Used		Unknown		#	%
Crash Severity	Minor/Moderate	#	3,545		4,161		428		8,134	76.50
		%	75.67	43.58	78.70	51.16	64.85	5.26		
	Severe/Fatal	#	1,140		1,126		232		2,498	23.50
		%	24.33	45.64	21.30	45.08	35.15	9.29		
	Column-Totals	#	4,685		5,287		660			
		%	44.07		49.73		6.21			

Table 9 shows the crash severity distribution by gender of the driver at fault. As can be seen, while male drivers accounted for 78.70 percent (see cell in green) of drivers at fault, they accounted for 92.35 percent (see cell in blue) of all severe/fatal crashes. Furthermore, out of all crashes caused by male drivers, 0.23 percent (see cell in yellow) resulted in severe/fatal outcomes.

On the other hand, out of all crashes caused by female drivers, 0.12 percent (see cell in orange) resulted in severe/fatal events. The same pattern may be observed for minor/moderate crashes (see cells in gray), but it is just not as pronounced as for severe/fatal crashes.

It is important to stress that the much higher percentage of drivers at fault being male obviously reflects the distribution of drivers in the Emirate of Abu Dhabi, where the large majority of drivers are males, so one should not necessarily conclude that male drivers cause more crashes since no exposure, in terms of total hours driven by driver gender, was taken into consideration. However, meaningful conclusions can be drawn as soon as: i) the percentage value in the green cell is compared to the percentage value in the blue cell, ii) the percentage value in the yellow cell is compared to the percentage value in the orange cell, and iii) percentage values in the gray cells are compared.

In sum, Table 9 suggests that male drivers are more prone to be the driver at fault in more severe injury crashes. This may be a relevant finding to not only driving training programs, but also to insurance companies as this suggests that insurance premiums should be priced accordingly.

Table 9. Crash Severity Distribution by Gender of Driver at Fault

			Gender						Row-Totals	
			Male		Female		Unidentified		#	%
Crash Severity	No Injury	#	987,739		155,347		113,469		1,256,555	99.16
		%	99.05	78.61	99.29	12.36	99.96	9.03		
	Minor/Moderate	#	7,174		927		33		8,134	0.64
		%	0.72	88.20	0.59	11.40	0.03	0.41		
	Severe/Fatal	#	2,307		182		9		2,498	0.20
		%	0.23	92.35	0.12	7.29	0.01	0.36		
	Column-Totals	#	997,220		156,456		113,511			
		%	78.70		12.35		8.96			

Table 10 shows the crash severity distribution by age of the driver at fault. It can be seen that 87.73 percent (see cells in green) of all drivers at fault were between 18 and 50 years of age, which may reflect the age range that the majority of drivers in the Emirate of Abu Dhabi fall within.

Furthermore, 434 crashes (see cell in blue) had a driver at fault aged less than 18 years, which is the minimum age to legally drive in the Emirate of Abu Dhabi. Even though this number of crashes involving minors as drivers at fault may be considered small relative to the total number of crashes (i.e., 1.26 million), minors were overrepresented in injury crashes. That is, while less than one percent (see cells in gray) of all crashes involving drivers at fault between 18 and 70 years of age were classified as severe/fatal, over 5 percent (see cell in orange) of all crashes involving minors as drivers at fault were classified as severe/fatal. In addition, minors were also found to be significantly overrepresented in the minor/moderate injury category (see cells in pink). Finally, even though injury crashes accounted for only 0.8 percent of all crashes, 18 percent of the crashes involving minors as the drivers at fault resulted in injuries.

Elderly drivers also appeared to be overrepresented in the injury categories (see cells in purple).

In sum, Table 10 suggests that, when minors are excluded, higher chances of injuries are associated with drivers that are more experienced and the elderly. This may be seen as a puzzling finding since previous research has shown that younger drivers have been associated with more severe crashes. Thus, this finding should warrant further investigation.

Table 10. Crash Severity Distribution by Age of Driver at Fault

			Age of Driver at Fault												Row-Totals	
			< 18		18 - 30		31 - 50		51 - 70		> 70		Unknown		#	%
Crash Severity	No Injury	#	354		516,702		586,812		120,458		4,773		27,456		1,256,555	99.16
		%	81.57	0.03	99.79	41.12	98.79	46.70	98.33	9.59	96.17	0.38	99.757	2.19		
	Minor/Moderate	#	56		816		5,490		1,579		143		50		8,134	0.64
		%	12.90	0.69	0.16	10.03	0.92	67.49	1.29	19.41	2.88	1.76	0.18	0.61		
	Severe/Fatal	#	24		267		1,672		471		47		17		2,498	0.20
		%	5.53	0.96	0.05	10.69	0.28	66.93	0.38	18.86	0.95	1.88	0.06	0.68		
	Column-Totals	#	434		517,785		593,974		122,508		4,963		27,523			
		%	0.03		40.86		46.87		9.67		0.39		2.17			

Table 11 shows the crash severity distribution by physical condition of the driver at fault. Only 0.17 percent (see cell in green) of all crashes appeared to have involved drivers who were under the influence of alcohol and/or illegal drugs. However, crashes that involved drivers who were physically impaired appeared to have a higher chance of producing injuries. Almost 100 percent of all crashes involving drivers who were not physically impaired resulted in no injuries (see cell in blue), while only 81.91 percent (see cell in yellow) of all crashes involving drivers who were physically impaired resulted in no injuries. These are very significant differences in no-injury-occurrence levels found between the physical condition categories.

It can also be seen that out of all the crashes that involved drivers at fault who were not under the influence, only 0.26 and 0.07 percent (see cells in gray) of them resulted in minor/moderate and severe/fatal injuries, respectively. On the other hand, out of all the crashes that involved drivers at fault under the influence, an astounding 15.77 and 2.32 percent (see cells in orange) of them resulted in minor/moderate and severe/fatal injuries, respectively. These are nothing less than very revealing numbers, suggesting that great focus may need to be placed on addressing impaired driving. Even though only 0.17 percent (see cell in green) of all crashes involved an impaired driver, these crashes produced a disproportionate number of injury crashes.

Hence, law enforcement may need to launch measures that will allow impaired drivers be effectively located, caught, and penalized. This may mean placing roadside patrols at strategic locations and times, as well as changing legislation in order to make impaired driving a crime that results in judicial prosecution and potential jail time. Countries may need to come to the conclusion that impaired driving is a real safety threat to society that needs to be addressed with appropriate measures rather than just fines and/or license suspension.

Table 11. Crash Severity Distribution by Physical Condition of Driver at Fault

			Physical Condition							
			Under the Influence		Not Under the Influence		Unknown		Row-Totals	
									#	%
Crash Severity	No Injury	#	1,802		1,209,734		45,019		1,256,555	99.16
		%	81.91	0.14	99.67	96.27	88.03	3.58		
	Minor/Moderate	#	347		3,184		4,575		8,106	0.64
		%	15.77	4.28	0.26	39.30	8.95	56.44		
	Severe/Fatal	#	51		900		1,547		2,498	0.20
		%	2.32	2.04	0.07	36.03	3.02	61.93		
	Column-Totals	#	2,200		1,213,818		51,141			
		%	0.17		95.79		4.04			

Table 12 shows the crash severity distribution by the seating position of the injured person. It does not include non-injury crashes since seating position information was available in injury data only.

Table 12 shows that the vast majority, 47 percent, of all injured occupants were drivers (see cell in light gray). Table 12 also shows that the percentages of severe and fatal injuries (i.e., 14 and 18 percent, respectively) for passengers sitting in the front (see cells in yellow), as well as the percentages of severe and fatal injuries (i.e., 13 and 15 percent, respectively) for passengers sitting in the back (see cells in blue), were slightly higher than those for drivers (i.e., 11 and 12 percent, respectively).

Even higher percentages were found under the “unknown” category (see cells in orange). It is likely that most, if not all, injured persons in the “unknown” category were non-motorists. Officers likely mark “unknown” when there were multiple passengers (i.e., besides the motorist) involved in the incident. On the other hand, in circumstances when the incident involved vehicles with one occupant each, identifying the seating positions is straightforward. Based on this reasoning, one could argue that sitting in a position other than the driver’s seat exposes one to a higher risk of more severe injuries, which could likely be due to higher prevalence of no seat belt usage among non-drivers. Unfortunately, this is just speculation as there was no link between seat belt usage and seating position data, which may be seen as a major limitation of this data. Thus, this is an issue that needs to be addressed as the Emirate of Abu Dhabi places more emphasis on high-quality crash-data-focused research.

Table 12. Crash Severity Distribution by Seating Position

			Seating Position								Row-Totals	
			Driver		Passenger Front Seat		Passenger Back Seat		Unknown		#	%
Vehicle Occupant Injury Severity	Minor/Moderate	#	5,824		1898		2090		1737		11,549	71.18
		%	75.76	50.43	66.71	16.43	71.75	18.10	62.46	15.04		
	Severe	#	868		413		384		449		2,114	13.03
		%	11.29	41.06	14.52	19.54	13.18	18.16	16.15	21.24		
	Fatal	#	995		534		439		595		2,563	15.80
		%	12.94	38.82	18.77	20.83	15.07	17.13	21.40	23.21		
	Column-Totals	#	7,687		2,845		2,913		2,781			
		%	47.37		17.53		17.95		17.14			

Table 13 shows the crash severity distribution by the driver-at-fault's nationality. Even though there were over 100 different nationalities entered into the crash database, it would not be practical to report the broken-down numbers for each one of those nationalities. As a result, nationalities were segregated into two different groups. One group was formed by the 4 nationalities which were found to have the highest number of drivers at fault, likely due to the large number of people from those countries living in the Emirate. This group included nationals from the UAE (25%), Pakistan (20%), India (14%), and Egypt (6%). Drivers from these nationalities were found to be at fault in almost two-thirds of all reported crashes (see cells in green). The other nationality group included nationals from countries that have a history of maintaining good road safety records, and/or of making significant investments in road design and safety research, as well as education. This group included nationals from Sweden (0.03%), the United States (0.64%), Australia (0.13%), and Japan (0.02%). Obviously, the number of nationals belonging to this latter group is much smaller simply because the number of people from these countries living in the UAE is significantly lower than the number of nationals belonging to the former group.

Table 13. Crash Severity Distribution by Nationality of Driver at Fault

		Crash Severity										Row Totals	
		No Injury		**Minor**		**Moderate**		**Severe**		**Fatal**		**#**	**%**
Emirati	#	316,165		744		2,099		391		517		319,916	25.46
	%	25.16	98.83	34.29	0.23	35.19	0.66	32.77	0.12	39.62	0.16		
Pakistani	#	256,394		418		1,235		273		281		258,601	20.58
	%	20.40	99.15	19.26	0.16	20.71	0.48	22.88	0.11	21.53	0.11		
Indian	#	175,153		205		608		138		125		176,229	14.02
	%	13.94	99.39	9.45	0.12	10.19	0.35	11.57	0.08	9.58	0.07		
Egyptian	#	76,535		111		279		64		48		77,037	6.13
	%	6.09	99.35	5.12	0.14	4.68	0.36	5.36	0.08	3.68	0.06		
Swedish	#	315		1		1		0		0		317	0.03
	%	0.03	99.37	0.05	0.32	0.02	0.32	0.00	0.00	0.00	0.00		
American	#	7,963		8		28		5		2		8,006	0.64
	%	0.63	99.46	0.37	0.10	0.47	0.35	0.42	0.06	0.15	0.02		
Australian	#	1,597		2		5		1		1		1,606	0.13
	%	0.13	99.44	0.09	0.12	0.08	0.31	0.08	0.00	0.08	0.06		
Japanese	#	233		0		0		0		0		233	0.02
	%	0.02	100	0	0.00	0	0.00	0	0.00	0	0.00		

The main takeaway from the numbers displayed in Table 13 is that drivers from certain nationalities appear to be more prone to be involved in more severe crashes. For example, while Emirati drivers accounted for 25 percent of the total crashes, they accounted for almost 40 percent (see cell in blue) of all fatal crashes and 32 percent of all severe crashes (see cell in orange). It is worth mentioning that Emiratis account for less than 20 percent of the total population living in the Emirate of Abu Dhabi, so the percent of Emirati drivers is even lower than that. Alternatively, 0.16

percent (see cell in gray) of all Emirati drivers were involved in a fatal crash, while 0.00 percent of all Swedish and 0.02 percent of all North American drivers (see cells in yellow) were involved in a fatal crash. Japanese drivers were involved in no injury crash.

In sum, percentage values look more favorable to the latter group than to the former group. Hence, fatal and severe injuries among drivers from the latter group were underrepresented, which may be an indication that there may be a real cause for the more likely involvement of nationals from the former group in more serious crashes. Identifying the real cause(s) for this may warrant further investigations. Nevertheless, differences in driving behavior/culture may be the major driving force behind the differences among these numbers. These numbers may also suggest that the car insurance of drivers from the former group may have been and may continue to be “subsidized” by drivers from the latter group.

4. Summary and Discussion

There have been significant improvements in the road safety field in the last decade not only in the UAE, but also in the GCC region as a whole. Nevertheless, the GCC countries have still been plagued with a relatively high number of traffic crashes and injuries that have taken a toll on their economies [3-11]. Despite being a real safety and economic problem, studies revealing statistics on the major causes and consequences of road crashes and injuries in the GCC region have been scarce. Thus, there is a significant need for publicly available road crash statistics in the region.

The objective of the present study was to collect and analyze a significant amount of road crash data in order to investigate the major contributing factors and consequences (i.e., in terms of crash severity level) of road-related collisions that occurred in the Emirate of Abu Dhabi. Considering that the Emirate of Abu Dhabi covers approximately 87 percent of the UAE’s land mass, it may be safe to say that the data used in this study may be considered a representative sample of the entire UAE. In fact, one could argue that the findings of this study may be relevant to the GCC region as a whole as well, considering the similarities between the UAE and its neighboring countries in terms of road/roadside design, driving behavior/culture, and traffic characteristics. The present study found that over 1.2 million crashes occurred in the Emirate of Abu Dhabi between the years of 2012 and 2017, while approximately 99 percent of these crashes did not result in an injury. It was also found that the months of May and June produced higher numbers of crashes as compared to the rest of the year. Higher numbers of crashes occurred between 8:00 and 16:00, while more severe injuries were produced between 22:00 and 5:59. It was also found that over 99 percent of all crashes occurred under clear weather conditions, whereas more severe crashes appeared to be significantly more prone to occur under rainy/stormy/dusty/foggy weather conditions.

The present study also found that side-impact and rear-end collisions were the most commonly observed crash types, while pedestrian-related collisions were significantly more violent encounters. Pedestrian collisions accounted for only 0.23 percent of all reported crashes; yet, they accounted for one-quarter of all fatal crashes. Tailgating, reversing, and reckless driving accounted for the vast majority of the reasons for crashes, 25 percent each. However, red light running and drunk driving were found to be more violent crashes. It was also found that 65 percent of all crashes occurred on roads with posted speed limits of up to 40 kph, while only 5 percent of all crashes occurred on roads with posted speed limits of 100-120 kph. Yet, almost 50 percent of all fatal crashes occurred on these higher-speed-limit roads. These are striking differences that signal the importance of greater design and law enforcement focus on roads with higher posted speed limits.

It was also found that almost 80 percent of all drivers at fault were males who were also more prone to be involved in more severe crashes. Furthermore, the study found that seat belt usage rates in the UAE may still be critically low considering that less than half of all injured people were wearing a seat belt. It is worth noting, however, that seat belt usage data was only available for injury crashes. Therefore, one could argue that unbelted people could be more prone to be in the injury crash data. The study also found that a small proportion of drivers at fault were minors (i.e., less than 18 years of age). However, minors were overrepresented in injury crashes, especially in fatal crashes. Furthermore, a very small percentage of drivers were found to be under the influence of alcohol or drugs; yet, crashes involving impaired drivers appeared to have a higher chance of producing injuries. It was found that the majority of injured people were drivers. However, percentages of severe and fatal injuries for non-motorists were slightly higher than those for motorists.

Finally, the data suggests that different nationalities may be exposed to different injury risk levels. For example, UAE nationals account for approximately 15 percent of the UAE's residents. This means that the Emirati driving population is actually less than 15 percent. However, Emiratis were found to be the driver at fault in 25 percent of all crashes, in 32 percent of all severe crashes, and in 40 percent of all fatal crashes. On the other side of the spectrum, while North Americans were found to be the driver at fault in 0.64 percent of all crashes, they were the driver at fault in nearly no fatal crashes. Comparisons like this may bring to light divergences indicating that different nationalities may be engaged in significantly divergent driving practices that may ultimately translate into different crash and injury rate levels.

5. Recommendations

Based on the findings from this study, the authors make the following recommendations:

1) Continued crash data collection and analysis in order to assess crash trends, as well as to help identify effective safety improvement countermeasures on an on-going basis,
2) Increased law enforcement during late hours,
3) Increased use of technology capable of mitigating the negative effects associated with dusty and foggy weather conditions,
4) Increased focus on tackling the problem associated with impaired driving, potentially leading to more extensive law enforcement in areas where and during times when impaired drivers may be more likely to be caught. This increased focus may also translate into changes in the traffic legislation by punishing impaired drivers more proportionally to the damage impaired driving activity may actually cause,
5) Increased focus on pedestrian-oriented road design and transport policies,
6) Improved safety and design standards, as well as increased enforcement presence, on higher-speed-limit roads,
7) Increased focus on improving signalized intersection safety, especially in terms of measures capable of preventing running-red-light events,
8) Increased educational campaigns and training programs devoted to driving-culture change as issues such as tailgating, reckless driving, and lack of seat belt usage appeared to be prevalent, and
9) Focused road safety educational campaigns specifically toward the Emirati driving community.

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