Article

Road Safety as a Public Health Problem: Case of Ecuador in the Period 2000–2019

Fabricio Esteban Espinoza-Molina ^{1,2,*} , Christian Fernando Ojeda-Romero ¹ , Henry David Zumba-Paucar ¹ , Giovanni Pillajo-Quijia ³ , Blanca Arenas-Ramírez ² and Francisco Aparicio-Izquierdo ²

- ¹ Transportation Engineering Research Group, Universidad Politécnica Salesiana (UPS), Cuenca 010102, Ecuador; cojedar@est.ups.edu.ec (C.F.O.-R.); hzumbap@est.ups.edu.ec (H.D.Z.-P.)
² University Institute of Automobile Research Francisco Aparicio Izquierdo (INSIA), Universidad Politécnica de Madrid (UPM), 28031 Madrid, Spain; blanca.arenas@upm.es (B.A.-R.); francisco.aparicio@upm.es (F.A.-I.)
³ Escuela Técnica Superior de Ingeniería y Diseño Industrial (ETSIDI), Universidad Politécnica de Madrid (UPM), 28012 Madrid, Spain; gp.pillajo@alumnos.upm.es
 * Correspondence: fespinoza@ups.edu.ec

Abstract: Background: Road safety is a significant public health problem because it causes negative consequences on victims and families. The objective was to analyze the most significant changes in traffic crashes in Ecuador during the period from 2000 to 2019. With data obtained from the National Institute of Statistics and Census, we performed the analysis to identify: the number of traffic crashes, the number of victims, and other study variables. Methods: Descriptive and analytical statistics and the contrast of proportions were used to analyze data from 2000 to 2019. Results: According to the ideal joinpoint analysis model, there was a significant decrease in the number of recorded traffic accidents from 2015 to 2019 of -8.54 per year, while the tendency to die increased in females (2.05 per year) and males (3.29 per year). The most common crash was a collision, and the automobile appeared as the most involved vehicle from 2015 to 2019. The hypothesis test contrast is used to determine if statistically significant differences exist between age groups by gender of the driver injured in the period 2017–2018. Conclusions: This study determines the most significant changes in the variables related to traffic crashes, where mortality due to this cause in the last four years has had a growth rate of 1.8% compared to collisions that presented a rate of -31.12% . The contrast of the hypothesis test shows significant differences in the injury level between males and female drivers, depending on the age group.

Keywords: traffic crashes; fatality; causes of traffic crashes; types of traffic crashes; joinpoint; risk assessment

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1. Introduction

Traffic accidents represent a problem that affects public health and road safety, giving rise to a mortality rate of 18.2 per 100,000 inhabitants worldwide, whereby the serious injuries generated by them are the eighth leading cause of death, causing 1.35 million deaths in 2016. They are currently the first cause of death in children and adolescents between 5 and 29 years old, generating 54% of deaths, which are vulnerable people such as pedestrians, cyclists, and motorcyclists. Ninety percent of deaths due to traffic accidents occur in low- and middle-income countries [1]. Therefore, the United Nations presented the Global Plan for the Decade of Action for Road Safety 2011–2020, where the goal is to halve the number of road traffic fatalities [2].

The Americas region shows an increasing trend in mortality due to traffic accidents [3]. In addition, Poswayo [4] states that traffic accidents are preventable, which means a reduction in the number of deaths and injuries. In 2016, deaths from this cause in this region cause 11% of deaths worldwide, with an average regional mortality rate of 15.6 per 100,000 inhabitants, and serious injuries represented the second leading cause of death in adolescents between 15 and 29 years of age.

The Pan American Health Organization [3] indicates that traffic accidents in Ecuador are on the rise and consequently produce more fatalities, which is why the National Road Safety Plan of Ecuador establishes as a goal a 40% decrease in deaths in the period 2015 to 2020 [5]; this means reducing the mortality rate from 19.47 in 2013 to 11.7 per 100,000 inhabitants by 2020 [6]. Furthermore, among the Sustainable Development Goals (SDGs), SDG 3.6 establishes reducing deaths by half. While SDG 11.2 mentions that everyone should have access to safe, affordable, accessible, sustainable transport systems and improved road safety by 2030 [2].

During the last three decades, Ecuador has had three traffic and road safety laws; approved on 10 April 1981, 2 August 1996, and 7 August 2008, respectively. The Organic Law of Land Transportation, Transit, and Road Safety of Ecuador (LOTTTSV) of 2008 was reformed on 29 March 2011, and at the end of 2014 again [7]. In addition, in 2016, the last reform of the enforcement regulations to the LOTTTSV was carried out; in it, essential changes were implemented such as the mandatory use of helmets for motorcycle drivers, recovery of driver's license points, having basic education certificate for non-professional licenses and high school diploma for professional licenses, a decrease in the level of alcohol allowed in the blood of drivers, and hardening of penalties [7,8], in addition to the regulation and control of the sale of alcoholic beverages applied since 2010 [9]. Despite this, Ecuador, like many countries, did not achieve goal 3.6 (reduce fatalities by half) [10]; therefore, it signed the second Decade of Action for Road Safety 2021–2030 to address this problem of traffic accidents [11], generating a public health problem in Ecuador.

There is a lack of scientific studies conducted in Ecuador, on the significant changes in the statistics of the number of victims (injured and dead), demographic characteristics, vehicles involved, time of occurrence, causes, and types of traffic accidents in different period. In addition, there is a need for accurate data on deaths and injuries due to traffic crashes, to assess the real dimension of the problem or to evaluate the effectiveness of intervention measures, and it is a problem to be solved. Moreover, the underreporting of road traffic injuries has to be considered in Ecuador as it is in other countries. The research objective is to analyze the most significant changes in the number of road traffic accidents recorded in Ecuador from 2000 to 2019, considering variables in this study such as: number of victims, demographic characteristics, vehicles involved, causes, schedules, and types of crashes, through regression lines with tie points and the Monte Carlo method to identify substantial changes. In addition, statistically significant differences between male and female drivers, in terms of accident rates on Ecuadorian roads, are analyzed through the methodology of contrast of proportions, using data from 2017 and 2018.

This article is structured as follows: Section 2 reviews the state of the art, focusing on studies involving variables that describe traffic accidents. Section 3 explains the sources of information where the data used in the study are available, presents the variables used, and describes the methodology used. Section 4 shows the results and discussion. Finally, Section 5 presents the main conclusions of this study.

2. State of the Art

Some studies analyze traffic accident patterns [12], risk behaviors [13,14], causes of traffic accidents [9,15], types of traffic collisions [8], and time of occurrence [16]. They also determine that the severity of accidents depends on the vehicles involved [17,18] and demographic characteristics [18–22]. In general, these investigations used historical data on traffic accidents and are descriptive. Several of them focus on recommendations to reduce the number of victims of traffic accidents and their consequences, such as the need to intervene to improve driver education for good driving behavior, improve vehicle safety, and provide better quality information for sound decision making.

Sex is an influential factor in road safety, as established in the literature [23–27].

Research on sex differences generally concludes that the crash rate or risk of being actively involved in a road traffic crash (especially fatal crashes) remains higher for

men [24,25,27–31], although the crash rate for both sexes is influenced by age in the first place, with higher rates for young [24,25,30,32,33] and older [30,32] drivers.

The researchers agreed, males have a higher accident traffic rate because they are more involved “voluntarily” in risky behavior, mainly among younger drivers, which are more prone to “search of excitement” and are less experienced drivers [24,25,31–33]. The authors [28,29,31,33] have concluded that males and young drivers are more likely to break the law. The study [34] concluded that females are easily distracted and incur more perception faults than males. In addition, other authors have stated that male’s higher accident traffic rates are related to higher exposure [31–33]. However, exposure data are hard to collect and unreliable, and recourse to alternative methods such as indirect or quasi-induced exposure is necessary [25,32,35–38]. The investigation [39] driver collision patterns addressed by sex and age regarding offenses, collision type, and injury severity using clustering methodology and tests of proportions are used for a complimentary analysis when driver offense is present, concluding there are significant differences between males and females, showing that this tool is very useful to support conclusions.

The 2020 Jharkhand (Republic of India) study shows that 73.4% of males and 26.6% of females died from traffic crashes, with the majority being in the 21–30 age range [20]. Furthermore, in Ghana (Africa) in 2017, males are six times more likely to die from traffic crashes than females, with the highest incidence of fatalities in the age ranges of children and the elderly [21].

Previous studies carried out in Latin America have determined certain dangerous behaviors that affect road safety, among which are: exceeding speed limits, driving under the influence of alcohol, not wearing seat belts, or engaging in distracted driving [40,41]. In addition, there is research such as that carried out in Chile, which shows that the time of day when most traffic accidents occur is in the afternoon [16].

In a study conducted in Brazil [12], they determine that the rear-end collision is the most common type of traffic accident; furthermore, in another study in this country, in the state of Piauí, they analyze historical data from 2000 to 2017, where they define that the vehicle with the highest number of traffic accidents and responsible for almost half of the deaths was the motorcycle [18].

Traffic accidents represent a problem studied in different countries, which measure the impact and propose solutions according to the situation of each country. In the case of Ecuador, the Congacha study [42] determined that 96.3% of traffic accidents are explained by ten causes, with inattentive driving being the predominant one, with an incidence of 56.8%, coinciding with other studies [9,15]. Another study conducted in Ecuador [43] states that the national statistics on traffic accidents collected by the responsible institutions have few variables which are not sufficiently disaggregated, and if they are available, not all of them are of good quality, which does not allow for more in-depth accident rate studies.

In Bhatti work [44], they state that underreporting exists in low-income countries, especially for light injuries [45], partly due to the lack of a well-structured data collection system [46,47]. This underreporting can be identified and avoided through police and hospital data reviews and software to standardize information [48], which is why it is essential to implement improvements in data collection in order to know the progress of road safety [49] and to allow comparison with other countries [50].

The National Traffic Agency (ANT) is the entity that keeps statistics on accidents and road accidents in the country. In recent years, it has categorized the probable causes of traffic accidents into 12 variables until 2013 and into 22 variables as of 2014 [51]. The variables collected in the official form of traffic accidents are in the following factors: (a) human factor, (b) vehicle factor, (c) environment factor, (d) to be defined, and (e) others, and it has not been possible to obtain from the official source, the concepts and cases encompassed in groups (d) and (e). From the exhaustive review carried out, two aspects stand out, namely the lack of and deficiency of information, on some crucial variables used to develop models that explain the causality of traffic accidents. The information collected at the accident site only allows general descriptive studies and obtaining the

overall mortality rate (traffic accidents per total population) for comparative purposes between countries and regions of the world.

In line with the above, the International Transport Forum recommends that Ecuador build and sustain capacity and investment in road safety research and data systems. In particular, it recommends the following: radically improving the vehicle registration system and providing a more effective means of vehicle regulation, collecting traffic and travel data to help assess risk exposure and analyze road safety problems [52]. From a Vision Zero perspective, it requires the continued analysis of historical crash data systems that must be accessible, structured, and secure in the first place. Countries leading the way in road safety have done so through robust, continuous, and sophisticated information systems. They can better assess the risks of road traffic deaths and injuries, prioritize road safety interventions based on accurate data, and track their outcomes.

Therefore, the main objective of this work is to analyze the most significant changes in the number of traffic accidents registered in Ecuador from 2000 to 2019 and if there are differences from the statistical point of view, in the level of injury of drivers by gender and age groups, according to data availability in two years (2017–2018).

3. Materials and Methods

3.1. Data Source

The data for this study came from the National Institute of Statistics and Census, specifically from:

From the transport yearbooks published from the period 2000–2019 of traffic crashes, this base prepared by INEC with data from the National Traffic Agency, from which extracted information for the following variables: (a) the number of traffic accidents, (b) the number of victims, slightly injured and seriously injured (on-site severity), (c) causes of traffic accidents, (d) types of traffic accidents, (e) vehicle involved, and (f) time of traffic crashes; all these variables are collected on site (24 h).

The General Death Statistical Register provided data on fatalities from 2000 to 2019. From this database, the variables obtained were (a) number of deaths by traffic crashes, (b) sex, and (c) age; the latter recorded since 2008. According to INEC's methodology, data are collected monthly and published annually [53].

The data for inference and contrast of proportions between men and women drivers are prepared by INEC with data from the National Traffic Agency [53], where data on the severity of drivers according to sex and age groups are displayed in two years (2017–2018).

3.2. Study Variables

The information on the variables used in the study is shown in Table 1. It is limited to the variables available in the accessible data on traffic accidents in Ecuador.

Table 1. The variables used in the present study.

Variable	Variable Type	Variable Implication
Causes of traffic crashes	Drunk driving	This variable is important because it helps to determine the behavior of road users according to categories.
	Lane drifting	
	Speeding	
	Driver recklessness	
	Pedestrian recklessness	
	Mechanical damage to the vehicle	
Types of traffic crashes	Failure to obey traffic signs	This variable identifies the most frequent types of traffic accidents in Ecuador. There are types of accidents with very harmful consequences for the occupants and people involved in them.
	Hit-and-run	
	Passenger drop	
	Collisions	
	Loss of track	
	Crashes	
	Friction inter vehicles	
	Overturn	

Table 1. Cont.

Variable	Variable Type	Variable Implication
Types of vehicles involved in traffic crashes	Automobiles Motorcycles Pickup trucks Sport utility vehicles (SUV) Buses Trucks	Vehicle categories were considered as values for this variable except bicycle (not collected), as the vehicle type implies adequate road safety control. This variable was collected from 2015 onwards.
Demographic characteristics	Sex Age	These two categories were considered in order to obtain a more in-depth analysis of the victims involved in traffic accidents. The age of the victim is recorded from the year 2008 onwards.
Severity of traffic crashes	Fatalities (total per year) On-site fatalities (recorded during 24 h) Minor injuries Serious injuries (trauma that can result in disability or death)	This variable determines the consequence of traffic accidents and helps to identify the severity of the problem. The category of seriously injured is recorded from 2000 to 2013 and from 2014 onwards, serious and minor injuries are unified into a single variable “injured”.

3.3. Study Method

Descriptive statistics were performed, showing summarized information of the data, presenting averages. The relationship between demographic characteristics (sex) and on-site victims (deceased, seriously injured, and slightly injured) was analyzed from 2000 to 2013 using the chi-square test, because as of 2014, the entities in charge stopped collecting these variables and recorded them as a single variable (injured) without disaggregation.

The traffic crashes recorded evaluated by regression analysis using Joinpoint software (Joinpoint regression software version 4.8.0.1—April 2020, available from the US National Cancer Institute’s Surveillance Research Program) [54]. The analysis performed in the software served to identify, through joinpoints, the most significant changes in the data entered, which helped identify the variables that are most relevant to the study, in addition to using the Monte Carlo permutation method present in the program to select the appropriate joinpoints by comparing two different joinpoints [55–57]. The Grid Search method was selected [58].

The program determined the Annual Percentage Change (APC), with a 95% Confidence Interval (CI) for each analysis performed, which adjusted the regression by the natural logarithm of the rate, where the independent variable was the years of the period analyzed. In addition, the Provided Average Annual Percentage Change (AAPC) was obtained, which is a measure of the entire range of data. In the data of gender and age of the victims, an advanced analysis called Pairwise Comparison was performed, which had the purpose of seeing if the two regression mean functions were similar using the Parallel test, where a value of $p < 0.05$ was statistically significant for the tests [59].

3.4. The Contrast Proportions and Rates’ Methodology

This section evaluates the differences between male and female drivers in terms of severity of crashes that occurred in Ecuadorian roads from data encompassing the period 2017–2018. Starting from the general perception, according to which there are behavioral differences assigned in both groups toward traffic problems, such as those related to the levels of risk assumed and to the respect for traffic rules, which directly influence the number and types of road crashes and the injury level of drivers, it is necessary to make a risk comparison taking into account gender as well age. To this end, the exposure plays a fundamental role, but it is not available because the complexity and the cost to obtain directly. To face this problem, the methodology of contrast proportions is used for the analysis of statistically significant differences in the severity of male and female drivers, according to age intervals, as the available and disaggregated data allow it (2017–2018).

3.5. Statistically Significant Differences between Males and Females Drivers Injured in Crashes

For statistically significant differences determination between male and female drivers involved in road crashes, regarding the harmfulness by age group, we have applied proportions and rates' contrast methodology.

The test of proportions tries to analyze whether the sample data allow rejecting the hypothesis of equality of proportions of a determined characteristic of two populations or, on the contrary, the differences between the proportions of the sample, obtained from the data, are too much to accept it or, in statistical terminology, not to reject it.

The statistic, i.e., the function of the data applied in this case, is the difference between the proportions divided by an estimate of the standard deviation of this difference:

$$d = \frac{\bar{P}_1 - \bar{P}_2}{\sqrt{\frac{\bar{P}_1}{n_1} + \frac{\bar{P}_2}{n_2}}} \quad (1)$$

The above equation, under the null hypothesis of equality of population proportions, is distributed approximately as a standard Gaussian; thus, when (d) takes values in the tails of the distribution, typically outside the interval $(-2,2)$, the hypothesis must be rejected, since the behavior of the samples is peripheral or inconsistent with what is expected if equality of proportions were to hold.

4. Results and Discussion

4.1. Data Descriptive and Regression Analysis by Joinpoint Results

The total number of traffic accidents and injury victims (fatalities and slightly and seriously injured), a ratio per 100,000 inhabitants, and their variations in the period 2000–2019 are presented in Table 2.

Table 2. Number of traffic crashes and fatalities recorded on site from 2000–2019 in Ecuador.

Year	Number of Road Traffic Crashes	Total Number of Casualties	Casualty Rate per 100,000	Difference of Victims per 100,000 Inhabitants	Deceased on Site	On-Site Fatalities per 100,000 Inhabitants	Difference in Deaths on Site per 100,000 Inhabitants	Injury	Light Injury	Serious Injury
2000	15,987	7710	61.5		1099	8.8		6611	5837	774
2001	11,008	4986	38.9	−36.8	816	6.4	−27.4	4170	4058	112
2002	12,215	6357	48.5	24.8	1038	7.9	24.5	5319	5236	83
2003	10,369	6841	51.4	5.8	1139	8.6	7.9	5702	5615	87
2004	16,323	10,128	74.7	45.5	1273	9.4	9.9	8855	8677	178
2005	16,578	10,697	78.0	4.3	1387	10.1	7.6	9310	9098	212
2006	18,572	11,312	81.0	3.9	1801	12.9	27.6	9511	9082	429
2007	19,598	13,882	97.7	20.6	1848	13.0	0.8	12,034	11,629	405
2008	19,664	12,627	87.2	−10.7	1343	9.3	−28.6	11,284	11,108	176
2009	21,528	17,032	115.6	32.5	1998	13.6	46.1	15,034	14,847	187
2010	25,588	22,485	149.8	29.6	2313	15.4	13.7	20,172	19,862	310
2011	24,625	21,211	138.9	−7.2	2049	13.4	−12.9	19,162	18,939	223
2012	23,854	20,524	132.2	−4.8	2242	14.4	7.6	18,282	18,210	72
2013	28,169	24,928	158.0	19.5	2277	14.4	−0.1	22,651	22,573	78
2014	38,658	29,990	187.1	18.4	2322	14.5	0.4	27,668		
2015	35,706	27,372	168.1	−10.1	2138	13.1	−9.3	25,234		
2016	30,269	23,425	141.7	−15.7	1967	11.9	−9.4	21,458		
2017	28,967	24,171	144.1	1.7	2153	12.8	7.8	22,018		
2018	25,530	22,009	129.3	−10.3	2151	12.6	−1.5	19,858		
2019	24,595	22,179	130.1	0.6	2180	12.8	1.2	19,999		

Note: ¹ There was no injury classification in recent years.

From 2000 to 2019, there were 447,803 traffic accidents in Ecuador, with a balance of 304,332 injured and 35,534 deaths on the spot. The most significant reduction concerning the previous year in traffic accidents occurred in 2001, with a decrease of 36.8% in the rate of victims per 100,000 inhabitants. The figures may have been due to the economic problems and political instability of the country in 2000 [60]. In addition, before the dollarization of

the economy (the year 2000), the country had a stagnant gross domestic product growth rate of 1.8% per year. In the following years, GDP averaged 4.4% [61], and this growth may have contributed to the increase in traffic accidents [62,63].

Within the period analyzed, the highest number of traffic accidents occurred in the year 2014 with 8.63% of the total number of accidents, while the lowest was in the year 2003 with a 2.31%. This figure could be due to the change in the Regulation to the Law of Ground Transportation, Transit, and Road Safety, which entered in January of that same year, where it reinforced the curricula for non-professional driver training schools and also modified the maximum blood alcohol limit allowed for driving (0.8 g/L) [8].

The analysis of the database of the National Traffic Agency from 2000 to 2019 reveals the absence of some variables such as data of road users (pedestrian, passenger, and driver), type of driving license, type of road, road conditions or weather conditions, vehicle damage, type and age of vehicle, and, in some years, it lacks the number of serious and minor injuries, age and sex of the victims, which ostensibly limits the possibility of the scientific study of traffic accidents with a greater level of depth. The crash data collection system needs to be improved and that it is essential to carry out studies to broaden the knowledge of road safety in Ecuador. Tools and resources for this purpose are appearing every day and require exhaustive, continuous, rigorous, and complete information systems. The variations in criteria over time make it practically impossible to carry out rigorous studies on the evolution of accident conditions and to evaluate the effects of measures for improvement [64]. The definition of policies and measures requires more and better knowledge extracted from the data.

About the previous paragraphs, traffic accident data for Ecuador from 2000 to 2019 were analyzed. Regression analysis using Joinpoint software helps to identify the most significant changes in the period. See Figure 1.

Figure 1. Analysis of traffic crashes joinpoints in Ecuador.

From Figure 1, the junction point in 2015 ($p = 0.0022$) stands out, demonstrating the most significant change in traffic accidents. In the period from 2000 to 2015, traffic accidents increased significantly by 7.65 per year (95% CI: 5.7 to 9.6), representing 75.58% of traffic accidents, which probably may be due to the average increase of 8.08% of the vehicle fleet

in Ecuador in those years [65,66], non-compliance with traffic law, vehicles with little or no safety equipment. As of 2016, they decreased by -8.54 per year (95% CI: -20.2 to 4.9), with 24.2% of the total number of traffic accidents; this decrease can probably be attributed has the reform of the land transport law regulation [67], in addition to the investment in road improvement, construction, and reconstruction [68], since these types of investments positively affect traffic accidents according to Calvo-Poyo study [69]. Likewise, the increase in breathalyzer tests for drivers and the implementation of computerized radars [70] have been part of the state surveillance program, which was demonstrated as a very effective measure to improve road safety in other countries.

Table 3 shows the types of vehicles involved in traffic accidents from 2015 to 2019 in Ecuador. Before 2015, this variable was not in the records. It is the type of vehicle against which people are impacted or occupied at the time of the accident, which is of utmost importance in crashworthiness and severity studies.

Table 3. The number of vehicles involved in traffic crashes in Ecuador from 2015 to 2019.

Year	Automobile	Motorcycle	Pickup	SUV	Bus	Truck	Other	Unidentified
2015	21,521	9107	7525	5342	3436	2370	3992	n/a ¹
2016	16,105	8072	5829	3851	2611	2292	2936	n/a ¹
2017	16,146	7533	5446	4151	2506	2360	2138	3517
2018	15,337	6653	4490	1842	1599	2428	945	21,834
2019	14,270	7256	4120	1893	1693	2367	948	6849

Note: ¹ Data not available in the ANT database.

From Table 3, the automobile participated in the highest number of traffic accidents with 35.74%, and the one with the lowest involvement was the truck with 4.70%. In addition, in the Joinpoint analysis, most of the vehicles involved in traffic accidents presented a decrease per year; automobile (-8.3), motorcycle (-6.3), pickup truck (-13.6), SUV (-24.5), bus (-17.4), and truck type was the only one that increased $+0.6$ per year.

In the work of Pillajo-Quijia [71], they apply machine-learning methods to explain the severity of driver injuries in hit-and-run accidents involving light commercial vehicles, such as vans and pickup trucks, and vehicle types are one of the influential factors.

The study conducted in the state of Piauí (Brazil) indicates that the motorcycle produced the highest number of deaths [18], while in Ecuador between 2015 and 2019 did not present any similarity; however, this may change in the future and will motivate studies. It is worth mentioning that in Ecuador, the growth rate of motorcycle sales between 2018 and 2019 was 12.31%, while the sales of automobiles decreased by 7.9% [72].

Table 4 shows the causes that have generated traffic accidents in the period 2000–2019 in Ecuador.

Table 4 shows that driver recklessness and carelessness is the predominant cause (representing 41.76%). Furthermore, the Joinpoint analysis indicates that from 2000 to 2013, this cause increased annually by 12.97 (95% CI: from 10.3 to 15.6), and since 2014, it decreased by -2.61 (95% CI: from -9.7 to 5.0). This result is similar to that obtained in previous studies from Ecuador [15,42]: the predominant cause is driver recklessness and carelessness, followed by speeding. A study conducted in Colombia on traffic fatalities also found that the causes with the highest fatality rate were reckless driving and speeding [41], and more examples can be found around the world.

The other causes did not show a decreasing trend over the years: disrespect of traffic signs (representing 9.49% of the causes of traffic accidents), invasion of oncoming traffic lanes with 9.07%, and speeding with 14.19%. The state of these results should motivate the monitoring and surveillance of compliance with the rules by the authorities in the field. Excessive speed is one of the principal causes of fatalities and minor injuries in traffic accidents, of which the WHO [1] points out that no corrective measures have been taken. There is sufficient evidence and agreement that an average 5% reduction in speed can lead to a 20% reduction in the number of fatal traffic accidents [5,73].

Table 4. Causes of traffic crash in Ecuador in the period 2000–2019.

Year	Drunkenness or Drug	Lane Encroachment	Excessive Speed	Driver Recklessness	Pedestrian Recklessness	Mechanical Damage	Disrespecting Traffic Signals	Other
2000	1804	1941	2646	3807	902	630	1061	3196
2001	1430	1893	1381	2842	851	502	885	1224
2002	1354	1845	1503	3739	870	408	709	1787
2003	1120	1265	1846	3619	798	243	175	1303
2004	1724	1983	2764	5739	1073	386	1237	1417
2005	1765	1998	2865	6080	1232	423	1018	1197
2006	1829	2458	3394	6192	1351	405	1163	1780
2007	1770	2613	4142	6561	1298	443	1419	1352
2008	1605	2200	3149	6728	1279	246	893	3564
2009	2172	2200	4615	8313	1366	371	1247	1244
2010	2633	1640	3685	13,548	1251	346	856	1629
2011	2484	964	3517	12,469	2004	398	1514	1275
2012	2001	1711	2112	12,504	1788	365	1197	2176
2013	2251	398	2292	14,662	2005	373	2224	3964
2014	2438	3001	3892	13,835	2075	393	8027	4997
2015	2400	4101	3777	11,965	1598	338	5244	6283
2016	2096	2526	3755	15,709	1241	229	3796	917
2017	2094	2616	4147	13,818	1442	188	3993	669
2018	1913	1584	4068	12,660	1155	284	3046	820
2019	1755	1678	4006	12,234	1317	170	2772	663

According to the Regulation to the Law of Ground Transportation, Transit, and Road Safety in force since 2016 in Ecuador, they modified the speed limits according to the type of public road (50 km/h in urban areas, 90 km/h in perimeters, 100 km/h in straights, 135 km/h in highways, and 60 km/h in curves) and school zones reduced from 35 to 20 km/h [67], compared to the 2009 Regulation, where they set three types of speed limits [74]. With these types of updates, Ecuador demonstrates that it has taken actions in speed enforcement, which can be associated with the decrease in traffic accidents as of 2016. In addition, this may be due to drivers' behaviors and the training they receive, as they do not respect speed limits and traffic signs [75].

Table 5 shows the timetable of occurrence of traffic accidents in Ecuador from 2015 to 2019.

Table 5. Traffic crashes according to the hour range in which they occurred during the period 2015–2019.

Year	0:00–5:59	6:00–11:59	12:00–17:59	18:00–23:59
2015	5308	9729	11,068	9601
2016	4666	8106	9175	8322
2017	4706	7565	8578	8118
2018	4654	6356	7416	7104
2019	4671	6144	6915	6865

The highest number of traffic accidents occurred between 12:00 am and 5:59 pm with 29.75%, coinciding with the study conducted in Chile [16], followed by 6:00 pm to 11:59 pm with 27.58%. The number of traffic accidents during the early morning hours was lower (16.55%) in Ecuador, which was a discrepancy with the study conducted in Cartagena (Colombia), where the highest number of traffic accidents occurred during the early morning hours [76].

The Joinpoint analysis showed a decreasing trend in traffic collisions during the following hours: from 0:00 to 5:59 h -2.55 (95% CI: from -7.0 to 2.7), from 6:00 to 11:59 h by -10.97 (95% CI: from -14.8 to -7.0), from 12:00 to 17:59 h by -19.90 (95% CI: from -14.0 to -7.7), and from 18:00 to 23:59 h by -7.96 per year (95% CI: from -4.7 to -7.6).

Figure 2 shows the changes in traffic accidents between two time slots in Ecuador from 2015 to 2019.

Figure 2. Comparison analysis of the schedules in which traffic crashes occurred in Ecuador, in the period 2015–2019.

The comparison of traffic crashes between the morning (0:00 to 11:59 h) and the afternoon (12:00 to 23:59 h) showed that the decrease in traffic crashes between the two schedules was parallel ($p = 0.10$) with a total reduction of -8.63 per year as shown in Figure 2.

Table 5 shows the number of fatalities by gender recorded in 24 h from 2000 to 2013.

In Ecuador, the number of males with light and serious injuries was double that of females between 2000 and 2013, as shown in Table 6. The chi-square analysis of the relationship between the variables of sex of the victims involved in traffic accidents and injury severity shows that the variables are independent, as concluded by other studies [23–27,59]. A recent work concerning gender in road safety has applied clustering analysis to the pattern identification in road crashes with two passenger cars in Spain [39].

Table 6. Number of victims of traffic crashes by gender in Ecuador in the period 2000–2019 (24 h on site).

Year	Deceased on Site		Lightless Injured		Severely Injured		<i>p</i>
	Female	Male	Female	Male	Female	Male	
2000	236	863	1994	3843	272	502	$p < 0.05$
2001	175	641	1371	2687	27	85	
2002	281	757	1718	3518	24	59	
2003	263	876	1845	3770	31	56	
2004	288	985	2847	5830	57	121	
2005	359	1028	3158	5940	60	152	
2006	464	1337	2898	6184	144	285	
2007	543	1305	3780	7849	130	275	
2008	264	1079	3572	7536	40	136	
2009	483	1515	5057	9790	71	116	
2010	460	1853	6548	13,314	116	194	
2011	399	1650	6391	12,548	87	136	
2012	470	1772	5982	12,228	26	46	
2013	463	1814	7368	15,205	33	45	

Table 7 shows the types of traffic accidents recorded in the period 2000–2019 in Ecuador.

Table 7. Types of the traffic crash recorded in Ecuador from 2000 to 2019.

Year	Hit-and-Run	Passenger Drop	Collision	Loss of Track	Crash	Friction Inter Vehicles	Overtake	Other
2000	2680	239	7801	225	2278	1543	785	436
2001	1912	93	5206	119	1780	774	719	405
2002	1933	82	5699	107	1984	1188	806	416
2003	1908	89	4424	133	1752	1001	796	266
2004	3165	237	7228	339	2698	1521	1026	109
2005	3133	288	7192	390	2755	1538	1113	169
2006	3641	342	8059	455	3061	1633	1184	197
2007	3595	277	8530	499	3424	1737	1137	399
2008	3475	217	8398	359	3161	1408	1153	1493
2009	4171	431	9397	693	3516	1425	1272	623
2010	4581	480	12,025	795	3898	1699	1288	822
2011	4505	434	11,632	1143	3900	1751	1104	156
2012	4147	488	10,936	1270	3602	1636	1088	687
2013	4769	564	13,145	1370	3811	1769	1103	1638
2014	6476	750	18,412	2545	4825	2735	1455	1460
2015	5431	810	17,137	3471	4624	2597	1054	582
2016	5075	834	13,745	3273	4017	2051	763	511
2017	4958	865	13,197	3501	3647	1813	617	369
2018	4288	762	11,629	2977	3417	1213	540	704
2019	3992	705	11,372	3064	3234	1248	416	564

The lowest number of traffic accidents was for passenger drops with 2%, and the highest was collisions, with an average of 45.29%. The Joinpoint analysis determined that passenger drops from 2005 to 2009 increased by 9.04 (95% CI: from 5.8 to 12.4) per year, and collisions from 2014 to 2019 decreased by -6.28 (95% CI: from -13.1 to 1.1). Both types of crashes should be trend-tracked. Pedestrian crashes are also significant in number; moreover, other vulnerable road users should be studied in dedicated works.

Collision is one of the most frequent configurations, and the severity changes according to the type of collision. Head-on collisions are the most injurious compared to rear-end collisions, and being the predominant accident type in Ecuador, there was no categorization until 2013. In the last years, a side collision represented 58.49%, followed by rear collision at 21.53%, frontal collision at 13.81%, and other collisions at 6.18%. Research conducted in Colombia shows that collisions between vehicles are the fourth leading cause of death [77]. In the study conducted in Brazil [12], rear-end collisions are the leading cause of traffic accidents.

Table 8 shows the variation of annual deaths concerning those registered in 24 h in the period 2000–2019 caused by traffic accidents and the ratio of deaths per 100,000 inhabitants in Ecuador.

The growth rate of the number of fatalities (annual) was 1.8% from 2015 to 2019. Table 8 shows that the number of males who die in traffic accidents is higher than that of females; approximately six males and two females die per day in traffic accidents in Ecuador. Other research [20,21] shows that sex is a factor that influences traffic accidents in several countries [23,26,27].

The average rate of deaths per 100,000 inhabitants is 18.2 in Ecuador between 2000 and 2019; the result obtained is close to those recorded in 2016 by countries in Latin America and the Caribbean, highlighting the worrying situation for several countries such as El Salvador, Paraguay, Guyana, and Belize with a rate value around 20 with a rate value around 20 deaths per 100,000 inhabitants [78]. If we compare this with the European region, which had a rate of 9.3 deaths per 100,000 inhabitants [79] in the same year, the dimension of the health problem to be faced in Ecuador becomes evident.

When comparing the annual death data between INEC and those recorded in situ (24 h) by ANT, there was an average variation of 35.97% between 2000 and 2019. This finding is very similar to that of other countries [43,45,48]. According to Furas's study, underreporting in Latin America varies from 12% in Colombia to 29% in Ecuador [80]. The situation is also affected by the lack of disaggregated variables in Ecuador, highlighting

the need for a well-structured data collection system, as recommended by international institutions for Ecuador [1,52].

Table 8. The variation between the recorded data of deaths on site (24 h) and deaths (annual) from 2000 to 2019.

Year	a	Deceased Male	Total Deaths	Deceases (24 h) ¹	Variation (%)	Deaths per 100,000 Inhabitants	Difference in Deaths per 100,000 Inhabitants
2000	444	1597	2041	1099	46.15	16.29	
2001	434	1465	1899	816	57.03	14.82	−9.02
2002	436	1523	1959	1038	47.01	14.96	0.96
2003	442	1568	2010	1139	43.33	15.09	0.86
2004	416	1427	1843	1273	30.93	13.60	−9.88
2005	514	1865	2379	1387	41.70	17.34	27.49
2006	546	1974	2520	1801	28.53	18.05	4.08
2007	524	2131	2655	1848	30.40	18.68	3.50
2008	503	2188	2691	1343	50.09	18.59	−0.45
2009	641	2535	3176	1998	37.09	21.55	15.90
2010	660	2644	3304	2313	29.99	22.01	2.13
2011	615	2736	3351	2049	38.85	21.95	−0.26
2012	655	2521	3176	2242	29.41	20.46	−6.78
2013	614	2532	3146	2277	27.62	19.94	−2.54
2014	626	2475	3101	2322	25.12	19.35	−2.98
2015	586	2537	3123	2138	31.54	19.18	−0.85
2016	574	2364	2938	1967	33.05	17.77	−7.35
2017	598	2419	3017	2153	28.64	17.98	1.17
2018	596	2546	3142	2151	31.54	18.46	2.64
2019	589	2590	3179	2180	31.42	18.65	1.05

Note: ¹ Data corresponding to deaths within 24 h after the crash.

Figure 3 shows the comparison from 2000 to 2019 in Ecuador according to the sex of those dead in traffic accidents (annually).

* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: female - 1 Joinpoint, male - 2 Joinpoints. Rejected Parallelism.

Figure 3. Comparison analysis of the number of fatalities in traffic crashes of male and female.

In the Joinpoint analysis, the most significant changes were identified in the number of deaths according to sex (per year), as shown in Figure 3, with females presenting an increase of 2.05 per year (95% CI: 1.2 to 2.9) and males increasing by 3.29 per year (95% CI: 2.3 to 4.3). In the comparability test, the number of deaths (males and females) due to traffic accidents was not parallel (the selected model rejected parallelism, $p = 0.0004$). There are international studies that conclude that females are involved in fewer traffic accidents [23,26,31,34]. Underlying these numbers are socioeconomic factors determining a higher number of males in the driver census. The late incorporation of females into the labor market, family characteristics, and other cultural barriers determines this configuration of driver censuses in large regions worldwide. For a rigorous comparison, it is necessary to have a measure of risk exposure, which is the mainstay of accident studies and, at the same time, one of the costliest variables to obtain (surveys, naturalistic studies, among others) from large sectors of the population to ensure its representativeness. Around the world, researchers are working on alternative means of elicitation, exploring new data sources, and in the Quasi-Induced Exposure (QIE) methodology, from data contained in accident databases. In the paper [81], they have developed a methodology for improving driver crash liability useful for the QIE approach. In addition, in research papers, it can be found that the age is a factor to be taken into account. In this paper, the methodology of contrast of proportions is developed to analyze the statistically significant differences in the severity of male and female drivers, according to age intervals, as the available and disaggregated data allow it (2017–2018). The analysis of the results can be found in Section 4.2.

Table 9 shows the age range of fatalities involved in traffic accidents registered in the period 2008–2019 in Ecuador.

Table 9. Age of fatalities due to traffic crashes during the period 2008 to 2019 in Ecuador (annual data).

Year	Ages Range									No Information
	<1	1–9	10–19	20–29	30–39	40–49	50–59	60–69	>69	
2008	6	168	316	685	478	372	226	193	244	3
2009	21	230	369	797	556	389	287	236	287	4
2010	11	213	356	809	546	433	356	251	318	11
2011	20	224	349	884	590	435	292	215	335	7
2012	15	205	355	811	573	384	308	217	304	4
2013	14	172	342	856	574	368	314	208	292	6
2014	13	158	312	827	554	378	313	222	324	0
2015	16	162	339	845	554	392	285	193	335	2
2016	16	155	264	740	531	401	279	236	315	1
2017	11	130	293	830	542	366	298	213	334	0
2018	12	125	311	862	588	380	321	228	313	2
2019	16	127	264	926	579	409	311	224	320	3

From Table 9, it is noteworthy that of those killed in road traffic accidents 26.44% belong to the age range of 20–29 years ($p = 0.03$), followed by the group of 30–39 years (17.85%) ($p = 0.01$), 40–49 years (12.60%) ($p = 0.04$), over 69 years (9.96%) ($p = 0.03$), 50–59 years (9.61%) ($p = 0.01$), and 1–9 years (5.54%) ($p = 0.01$). The study conducted in Jharkhand (Republic of India) and those conducted by WHO, PAHO, and OISEVI coincide with the age range of the highest number of road traffic fatalities, which is 20–29 years [1,3,20,75], but unlike the work conducted in Ghana [21], the results are different, with the most vulnerable road users being children under ten years of age and the elderly.

Figure 4 shows the comparison analysis obtained from 2000 to 2019 in Ecuador, according to the age of those killed (annually) in traffic accidents.

* Indicates that the Annual Percent Change (APC) is significantly different from zero at the $\alpha = 0.05$ level.
 Final Selected Model: 0 and 39 years - 2 Joinpoints, 40 years and more - 2 Joinpoints. Failed to reject Parallelism.

Figure 4. Comparison analysis of deaths occurring in ages 0–39 years and 40 years and older.

Two age groups were analyzed by the comparison method, as shown in Figure 4, where the result was parallel ($p = 0.137$), and the number of deceased persons in both ages ranges from 0 to 39 years and 40 years and older increased by 0.22 per year (95% CI: -0.6 to 1.0).

4.2. Hypothesis Tests Results

We want to analyze the sample data to either not reject the hypothesis of equal proportions of a given characteristic of the feature of two populations or to do so if the differences between the sample proportions are too larger, considering the statistical (d) value (defined in Section 3.4) to accept or reject the hypothesis test.

In Table 10, the number of injured drivers in accidents traffic in Ecuador in the period 2017–2018 segregated by injury level according to the sex and age group is shown. The figures agreed with it is known: if absolute numbers are analyzed, there are more injured males than females, in all the levels of injury and each age group. It is important to keep in mind that the exposure is different between them, and as mentioned above, the exposure is not simple or directly available. To solve the problem, the risk comparison is made using the contrast proportions methodology to determine if there are significant differences in the proportion by injury level by sex and age intervals. The proportions are computed concerning the total of males or females, respectively, and we analyze if the differences between the sample proportions, as obtained from the data, are too large to accept in the statistical terminology, not to reject it. The results of the contrast are in Table 11.

Table 10. Data of the injury of the driver according to the sex and age group in the period 2017–2018.

Sex	Age Group	Deceased	Injury	No-Injury	Unknown
Male (M)	18 to 30	494	3.842	1931	6
	31 to 55	449	3400	3265	7
	56 to 75	90	587	804	1
	>76	20	117	148	4
	Global	1053	7946	6148	18
Female (F)	De 18 a 30	13	316	159	0
	De 31 a 55	12	411	327	0
	De 56 a 75	4	48	40	0
	>76	0	5	4	0
	Global	29	780	530	0

Table 11. Hypothesis tests of the driver' injury by sex and age group in the period 2017–2018.

Severity of Driver	Age Group	Sex	CI. Low	CI: Up	Mean	Normal St.	Ratio M/F
Deceased	18 to 30	M	0.0719	0.0856	0.0787	1.65	2.96
		F	0.0121	0.0412	0.0266		
	31 to 55	M	0.0573	0.0688	0.0631	8.82	3.94
		F	0.0068	0.0252	0.0160		
	56 to 75	M	0.0483	0.0731	0.0607	1.8	1.40
		F	0.0010	0.0860	0.0435		
	>76	M	0.0393	0.0991	0.0692	—	—
		F	0.0000	0.0000	0.0000		
	Global	M	0.0653	0.0736	0.0694	9.03	3.21
		F	0.0137	0.0296	0.0217		
Injury	18 to 30	M	0.6002	0.6248	0.6125	−0.23	0.95 (1.05)
		F	0.6043	0.6908	0.6475		
	31 to 55	M	0.4656	0.4893	0.4770	−2.55	0.87 (1.15)
		F	0.5117	0.5843	0.5480		
	56 to 75	M	0.377	0.4215	0.3961	−3.87	0.76 (1.32)
		F	0.4176	0.6259	0.5217		
	>76	M	0.3471	0.4626	0.4048	0.00	0.73
		F	0.2243	0.8869	0.5556		
	Global	M	0.5159	0.5321	0.5240	−2.39	1.10 (0.90)
		F	0.5556	0.6095	0.5825		

Note: The inverse ratio is indicated in parentheses (ratio F/M).

The existence of significant differences is measured by the 95% threshold for the normal statistic which is 2. In Table 11, the mean value and Low and Up CI are shown beside the normal statistic of the hypothesis test contrast, besides the ratio between the proportions.

In road collisions in Ecuador of the period analyzed, there exist significant sex differences for injured levels regarding the age group. In the case of deceased level, the risk is different by gender in the 31–55 years age group, and the differences decrease to be not significant for more younger and senior drivers by gender. The ratio between the proportions in Table 11 is $M/F = 2.96$ from 18 to 30, 3.94 from 31 to 55, and 1.40 in the interval of 56–75 years.

In the injury level, the contrast of the hypothesis test allows one to conclude that there is more risk to be injured within the sample of female drivers, and there are significant differences with males in two age groups encompassing from 31 to 75 years. The ratios indicate a larger proportion of females in these intervals (1.15 and 1.32, respectively).

This analysis remarks the importance of ratios analysis, instead of absolute numbers, showing that conclusions can differ depending on gender and age.

4.3. Limitation of the Study

This study used the information on traffic accidents, available annually from INEC; in which, there was no disaggregation of variables, for example, types of collisions, road users, and did not record light and serious injuries as of 2015. From 2019, the data improved, but they are still unreliable.

The availability of disaggregated information for drivers in two years (2017–2018) made it possible to apply the contrast of hypotheses, leading to conclusions with significant nuances.

5. Conclusions

We conclude that from 2000 to 2014, the decrease in traffic collisions has not been constant; there are years when they increase. In addition, the number of deaths has increased in most years, making road safety a public health issue for Ecuador. The analysis of the results indicates that since the new traffic law came into force in Ecuador at the end of 2014, there has been a 31.12% decrease in the number of traffic accidents up to 2019. Despite this decrease, traffic fatalities show a worrying growth rate of 1.8%, and if this trend continues, Ecuador has not met the target 3.6 of the SDG 2020 and has to adopt its measures to comply with the new decade on road safety until 2030.

The analysis revealed that 41.76% of traffic accidents in Ecuador are caused by recklessness and carelessness of drivers, such as: driving inattentive to traffic conditions, driving while drowsy or in poor physical condition, and not keeping the minimum lateral safety distance between vehicles, which, in general, are risky behaviors on the road. In addition, the type of traffic accident with the highest incidence is a collision with an average of 45.29%. From 2015 to 2019, the automobile has a higher probability of collision with 35.74%, and motorcycles have a lower probability of collision with 16.55%. The predominant time of traffic collisions recorded from 2015 to 2019 arises in the afternoon hours between 12: 00 and 17:59 with 29.75%.

The analysis by sex shows that men are more likely to die in traffic accidents, with an average of approximately 2182 (80%) deaths, and women 551 (20%) deaths in the period studied, the most affected age range is between 20 and 29 years of age, followed by those between 30 and 39 years of age. From these data, it is not known whether the victims correspond to pedestrians, drivers, cyclists, and other road users, because it is not recorded by those responsible for road safety.

The hypothesis test analysis remarks the importance of considering ratios instead of absolute numbers, showing significant differences between males and females, depending on the age group and level of injury. In the case of deceased level, the risk is different for males and females in the 31–55 years age group, and the differences decrease to be not significant for more younger and senior drivers of both sexes. The ratio between the proportions in Table 11 is $M/F = 2.96$ from 18 to 30, 3.94 from 31 to 55, and 1.40 in the interval of 56–75 years.

For the injury level, the hypothesis test contrast allows one to conclude that there is a higher risk of being injured within the sample of female than men drivers, and there are significant differences between them in two age groups: from 31 to 75 years old. The ratios indicate a higher proportion of females in these intervals (1.15 and 1.32, respectively).

Finally, the data analysis remarks the recording process must be improved; this would contribute to aid future research to learn about the worried health problem and the influencing factors and would propose more concrete solutions to reduce traffic crashes in Ecuador.

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