



# Years of Life Lost and Spatial Distribution of Mortality due to Roadway Incident in Medellín, 2010-2020\*

Años de vida perdidos y distribución espacial de la mortalidad por incidente vial en Medellín, 2010-2020

Anos de vida perdidos e distribuição espacial da mortalidade por incidente de trânsito em Medellín, 2010-2020

Edwin Alberto Salazar Henao<sup>1</sup>; Gustavo Alonso Cabrera Arana<sup>2</sup> †

<sup>1</sup> Master's in Epidemiology. Universidad de Antioquia. Colombia. ealberto.salazar@udea.edu.co. orcid: <https://orcid.org/0000-0002-1075-7782>

<sup>2</sup> PhD in Public Health. Universidad de Antioquia. Colombia. gustavo.cabrera@udea.edu.co. orcid: <https://orcid.org/0000-0003-3819-9185>

Received: 18/11/2021. Approved: 13/02/2023. Published: 20/03/2023. Traduced: 15/11/2023

---

Salazar-Henao EA, Cabrea-Arana GA. Years of Life Lost and Spatial Distribution of Mortality due to Roadway Incident in Medellín, 2010-2020. *Rev. Fac. Nac. Salud Pública.* 2023;41(2):e347846. DOI: <https://doi.org/10.17533/udea.rfnsp.e347846>

---

## Abstract

**Objective:** To estimate the potential years of life lost and the spatial distribution of mortality from road incidents by mode of transport in Medellín 2010-2020, as a baseline for the implementation of the Vision Zero strategy of the World Health Organization in the city's mobility. **Methodology:** This is a retrospective and descriptive cross-sectional study, with a secondary source. The calculation of the potential years of life lost was made using the life expectancy at birth in Colombia as the age limit, according to year and gender. The spatial analysis was carried out from the direction of the incident; Kernel density was represented by the standard-

quantile classification method, and the zones of influence were created by the multiple ring buffer method, with distances of 500 and 1000 meters. **Results:** Between 2010 and 2020, Medellín registered 2,988 deaths due to road incidents. Those who died the most were pedestrians, with 1,423 (47.6%) deaths, followed by motorcyclists, with 1,295 (43.3%). Potential years of life lost were 98,787. The zones (comunas) with the highest concentration of pedestrian deaths were: Candelaria, Buenos Aires and Manrique; in motorcyclists, the highest concentration was evidenced in the river road system. By areas of influence, pedestrians killed within a radius of

---

\* This research derived from the inter-administrative contract N.º 4600090152 between the Secretariat of Mobility of Medellín and the National Faculty of Public Health at Universidad de Antioquia, and registered in the Extension Center of the same Faculty for 2021, as "Support for the social and educational management of the Mobility Secretariat of Medellín". The following text also emerged from the same research: Salazar E. Potential years of life lost and spatial analysis of roadway incidents in pedestrians from Medellín 2015-2020. *Revista Médica de Risaralda.* 2021;27(2):34-53. DOI: <https://doi.org/10.22517/25395203.24908>.

† The Revista Facultad Nacional de Salud Pública regrets the death of the former director of the journal, author of this article and Doctor in Public Health Gustavo Alonso Cabrera Arana (July 21, 2022).

1,000 meters from the river road system were 688 (49.8%), and motorcyclists, 636 (52.2%). **Conclusion:** Motorcyclists were the ones who died the youngest and the most years they stopped living. Polytrauma is a constant diagnosis of death,

but injuries to the head, skull and thorax are more lethal in pedestrians and motorcyclists.

-----**Keywords:** potential years of life lost, life expectancy, traffic accidents, mortality, premature death, geographic information systems.

---

## Resumen

**Objetivo:** Estimar los años potenciales de vida perdidos y la distribución espacial de la mortalidad por incidente vial según modo de transporte en Medellín 2010-2020, como línea base para la implementación de la estrategia Visión Cero, de la Organización Mundial de la Salud, en la movilidad de la ciudad. **Metodología:** Estudio retrospectivo y descriptivo de corte transversal, con fuente secundaria. El cálculo de los años potenciales de vida perdidos se hizo tomando como edad límite la esperanza de vida al nacer de Colombia, según año y género. El análisis espacial se realizó a partir de la dirección del incidente; la representación de la densidad de Kernel fue por el método de clasificación estándar-cuantil, y las zonas de influencia se crearon por el método búfer de anillos múltiples, con distancias de 500 y 1000 metros. **Resultados:** Medellín, entre 2010 y 2020, registró 2988 muertes por incidente vial. Quienes más murieron fueron los peatones, con 1423 (47,6 %)

muertes, seguidos por los motociclistas, con 1295 (43,3 %). Los años potenciales de vida perdidos fueron 98 787. Las comunas de mayor concentración en muerte de peatones fueron: Candelaria, Buenos Aires y Manrique; en motociclistas, la mayor concentración se evidenció en el sistema vial del río. Por zonas de influencia, los peatones fallecidos en un radio de 1000 metros del sistema vial del río fueron 688 (49,8 %), y los motociclistas, 636 (52,2 %). **Conclusión:** Los motociclistas fueron quienes murieron más jóvenes y más años dejaron de vivir. Politraumatismos son diagnósticos constantes de muerte, pero lesiones en cabeza, cráneo y tórax son más letales en peatones y motociclistas.

-----**Palabras clave:** años potenciales de vida perdidos, esperanza de vida, accidentes de tránsito, mortalidad, muerte prematura, sistemas de información geográfica.

---

## Resumo

**Objetivo:** Estimar os anos potenciais de vida perdidos e a distribuição espacial da mortalidade por incidente de trânsito segundo o modo de transporte em Medellín 2010-2020, como linha base para a implementação da estratégia Visão Zero, da Organização Mundial da Saúde, na mobilidade da cidade. **Metodologia:** Estudo retrospectivo e descritivo de corte transversal, com fonte secundária. O cálculo dos anos potenciais de vida perdidos foi feito considerando como idade limite a esperança de vida ao nascer da Colômbia, segundo ano e gênero. A análise espacial realizou-se a partir do local do incidente; a representação da densidade de Kernel foi pelo método de classificação padrão-quantil, e as zonas de influência criaram-se pelo método buffer de anéis múltiplos, com distâncias de 500 e 1000 metros. **Resultados:** Medellín, entre 2010 e 2020, registrou 2988 mortes por incidente de trânsito. O maior número de mortes foi de pedestres, sendo

1423 (47,6%), seguido pelo de motoqueiros, sendo 1295 (43,3%). Os anos potenciais de vida perdidos foram 98.787. As localidades com maior concentração de mortes de pedestres foram: Candelaria, Buenos Aires e Manrique; no caso dos motoqueiros, a maior concentração evidenciou-se no sistema viário do rio. Por zonas de influência, os pedestres falecidos em um raio de 1000 metros do sistema viário do rio foram 688 (49,8%), e os motoqueiros 636 (52,2%). **Conclusão:** Os motoqueiros foram quem morreram mais novos e mais anos deixaram de viver. Politraumatismos são diagnósticos constantes de morte, mas lesões na cabeça, no crânio e no tórax são mais letais em pedestres e motoqueiros.

-----**Palavras-chave:** anos potenciais de vida perdidos, esperança de vida, acidentes de trânsito, mortalidade, morte prematura, sistemas de informação geográfica

---

## Introduction

Human mobility is a characteristic that has shaped civilization since its earliest stages, allowing humans to evolve, improve their living conditions, and conquer new and better lands to live, work, or interact as species. However, the right to exercise it in conditions of safety, accessibility, efficiency, sustainability, and inclusion ex-

ceeds the limits of freedom, given that this right is not absolute. For example, article 24 of the Constitution of 1991 protects the right to freedom of movement from two meanings: first, it is the right to move within the territory and to leave it, especially on the roads and public space and, second, the right to reside and remain in Colombia. Nevertheless, said constitutional norm establishes that it is not an absolute right and that it can be limited by law, even by aspects, like deprivation of

public space and roads, poor parking, poor classification of land, use of public space for commercial activities, or the country's security and conflict conditions that prevent us from moving and exceed our freedom.

Likewise, this mobility is restricted by human, social and normative variables, like socioeconomic level, academic level, international agreements, norms, decrees, and laws that restrict human mobility, norms of entry of safe vehicles with high safety standards and low emissions, among others. All these variables influence directly on safety, accessibility, efficiency, and sustainability. These variables determine and increase exposure to roadway risk, given that their mediation, in the mobility process, promotes inappropriate behaviors associated with deficiencies in roadway infrastructure and safe vehicles, raises the probability of suffering a roadway incident with higher fatal consequences due to increased exposure to roadway risk, which leaves daily approximately 4,000 deaths and millions of injured individuals who endure trauma or severe sequelae, with affection principally in adolescents and young adults who are in the most productive stage, and which generates negative impact on the economy, society, and quality of life of the families. These factors make roadway deaths a Public-Health challenge of over a century of evolution, since the massification of motor vehicles [1,2].

Roadway incidents lead to the deaths of 1.4-million people worldwide every year, being the principal cause of death among youth from 15 to 29 years of age. Male youth have three times more probability of dying in an incident compared to women; 73% of deaths occur in men < 25 years of age. These are premature, avoidable deaths that constitute an old, growing and priority problem in the modern world, given their frequency and harmful effects, mainly due to the loss of current and future workforce of nations, with greater incidence in poor countries, where costs of roadway incidents rise to 3% of their gross domestic product and which are product of expenses in medical treatments, loss of productivity of the people who die or become disabled due to lesions or trauma, and loss of work or study time that family members of the injured must allocate to care for the victims [3].

Roadway deaths affect disproportionately those most vulnerable on the road, pedestrians, cyclists, skaters, and motorcyclists, who due lack or deficiency of protection elements that can absorb the impact, given differences in mass and because of the speed of vehicles suffer more severe lesions and trauma. According to the World Health Organization (WHO), the most-vulnerable roadway users represent over half of all roadway deaths globally: motorcyclists constitute 28% of all mortal victims; pedestrians, 23%; and cyclists, 3% [4,5].

In the Americas region, 155,000 people die per year in roadway incidents, 12% of the world's deaths due to

roadway incident. Because epidemiological and contextual analysis is not carried out for the publication of these statistics, this figure hides that deaths from this cause are distributed unequally from one country to another. Moreover, their distribution is not commensurate with income level, and the burden of mortality is greater in middle-income countries than in high-income countries; 73% of deaths due to this cause take place in middle-income countries and 26% in high-income countries, indicating disproportion in relation to the motorization level [5]. The remaining 1% corresponds to poorly classified causes and missing or inconsistent data.

In many countries in the world, especially those with emerging economies, the risk of injury or roadway death depends on diverse social determinants, like driving under the influence of alcohol, excess speed, displacement mode, as well as the level of urban development and roadway infrastructure [4]. Although countries in the Americas have incorporated interventions to reduce roadway risk, progress has been slow. States must hurry in the application of effective roadway safety measures to meet the goals proposed by the United Nations and adopted in the *sustainable development goals* (SDG), to reduce by 50% the deaths and trauma caused by roadway incidents globally. In 2030 is the end of the SDG and of the new decade of action on roadway safety, so, without effective measures, Medellín and the world will repeat the failure observed between 2010 and 2020, which did not achieve the goals proposed of reducing deaths and roadway injuries [1,2].

In Colombia, between 2010 and 2020, 68,472 people died in roadway incidents, on average 6,224 deaths/year. Roadway mortality has remained among the 10 first causes of death, in the eighth place, and the second in the group of violent deaths, after homicide [6,7]. In 2019, 175,604 roadway incidents were registered, 743,977 injured and 40,563 seriously injured, which generated 45,525 hospitalizations. Among the 6,495 deceased in 2019, the most significant percentages were 54% of motorcyclists, and 25% of pedestrians; approximately 70% of these died the same day of the incident, due to the forcefulness of the impact and serious trauma [6].

In the last decade, Medellín was among the first three cities in the country with higher roadway deaths, together with Bogotá and Cali [7]. Although the city, in the last 10 years, has had slight drops in roadway mortality, and stands out due to actions, like the adoption of the Vision Zero strategy, by the WHO, to reduce mortality due to road incidents—which accepts that, as such, “accidents” do not exist, rather, they are preventable incidents, and it is considered that it is morally irresponsible that people die due to going to school, bicycling, or going to work—the roadway death rate is still high, being above 10 for every 100, 000 inhabitants, a very high figure with respect to international parameters [8].

Vision Zero, as city strategy, requires organizational structure, leadership, and transversal actions at intra- and inter-institutional level that allow reaching a historical milestone of zero deaths on city roads in the long term, therefore, in the medium term, meeting the goals of the “2020-2023 Future Medellín Development Plan” of reducing the roadway mortality rate from 10 to 5 per 100,000 inhabitants requires institutional and citizen commitment [9].

Adopting the Vision Zero strategy, meeting the goals proposed in the Development Plan, and reducing the mortality rates mentioned merits analysis, comprehension of the phenomenon, and estimation of a base line that describes and explores the characteristics of roadway mortalities according to the mode of transport, which permits focusing interventions in the territory from the institutional, technical, and social levels, and enables future measurement, monitoring, and comparison that guide decision making on the implementation of the Vision Zero strategy [8,9].

Due to the foregoing, this research sought to estimate the potential years of life lost and the spatial distribution of mortality due to roadway incidents according to mode of transport in Medellín, between 2010 and 2020, as base line to implement the Vision Zero strategy in mobility. Further, it permits knowing how the city is facing this phenomenon over a period of time, evaluating it in the future and whether the actions implemented as part of the Vision Zero strategy as of 2020 have any effect on mortality. Incidentally, this analysis supports or justifies implementation of the strategy, decision making, and allocation of resources.

## Method

Retrospective and descriptive cross-sectional study, with secondary source, collected through the Information System Network of Missing Persons and Corpses, web platform that exchanges information from entities and serves as effective tool for registration processes of missing persons and information about corpses subjected to medical-legal autopsy in Colombia and which permits judicial authorities to identify cases [10,11]. The database was provided by the National Institute of Legal Medicine and Forensic Sciences (INMLCF, for the term in Spanish).

The study population was comprised by the total tabulated death records by the INMLCF, like violent deaths associated to transportation events and classified according to mode, such as: pedestrian, motorcycle, automobile, and cyclist.

No procedure or sample selection was carried out. All the records that met the following criteria were analyzed: registration of person killed by roadway incident in Medellín; death occurring from 2010 to 2020,

and records of roadway deaths classified according to mode of transport.

The geographic analysis excluded records in which the variable “address of occurrence” was without information or poorly filled out according to standards of completeness and accuracy.

The calculation of the potential years of life lost (PYLL) was conducted according to WHO recommendations, and *premature death* was defined as that occurring prior to reaching the maximum life expectancy [12,13].

The PYLL are a summary measure that illustrates the loss society suffers as a result of the death of young people or of premature deaths; it is an estimation of how many more years the person could have lived if they had not died. This indicator takes into account the number of deaths due to a cause and the distribution of people according to age group [14,15].

As they are conceived, the PYLL apply more weight to the deaths of young people than to deaths of older individuals, given that the young lose more years of life upon dying [15].

The age limit was the life expectancy at birth (LEB) for Colombia, estimated by the National Administrative Department of Statistics (DANE, for the term in Spanish) according to gender and year, with values ranging between 2010 and 2020 from 71 to 74 years for men, from 78 to 80 years for women, and from 74 to 77 years for both sexes [16].

The “age” variable was organized into five-year groups, and for each of these groups the statistical measure “class mark” was estimated.

The *weighting factor* is the result of the difference between the LEB and the class mark. To obtain the PYLL, the weighting factor was multiplied by each of the deaths in each age group.

Lastly, the *index of potential years of life lost* (IPYLL) is the result of the division between the PYLL and the population projections by age group and year by DANE, multiplied by 100,000 [13].

Geo-coding of deaths due to roadway incidents was performed according to the incident’s address of occurrence, with this variable being previously normalized and standardized according to geolocation parameters. Occurrence sites were located using the massive Medellín geocoder “MapGis” (open use), which takes the address table and uses a geolocator to create dot features that represent the locations of addresses in a geographic space, permitting, through a single identifier, to unambiguously distinguish an entity [17,18].

The percentage of addresses geocoded and located on the road network was 97% for pedestrians, 97% motorcyclists, 95% automobiles, and 99% cyclists. Those not found were revised one by one, to detect possible errors,



which enabled increasing the global location percentage by 1%, thus, dismissing 3% of cases due to non-location.

After geocoding the addresses, maps were made using the Kernel density function for point entities, “which calculates the density of point entities around each output raster cell [...]” [19]. The surface value is highest at the point location and decreases as the distance from the point increases” [20].

The spatial representation of density was conducted through the standard-quantile classification method, where “each class contains the same number of entities, and the quantile assigns the same number of data values to each class; there are no empty classes, or with too few or too many values” [21]. Application of this method displays the classes through a color ramp that goes from light to dark, with the dark classes having the highest value; this permits identifying spatially sites with low or high density [22].

The creation of zones of influence with proximity to the Medellín River road system was conducted through the multiple-ring buffer method, with distances of 500 and 1,000 meters, taking as reference point the river road system, comprised by *Avenida Regional*, *Autopista Sur*, and *Avenida Paralela*, strategic corridor with high vehicle capacity that concentrates the largest proportion of roadway incidents, making this road system that crosses the city from north to south the most fatal, where incidents between trucks and motorcycles cause an average of one death per month [23].

This technique permits creating zones of influence at specific distances and around an input entity, permitting quantification of cases within said zones. The rings generated were classified by color range to delimit the proximity pattern, with the darkest being the closest [22].

Layers in Shapefile (SHP) format for information geo-referencing were downloaded from Medellín’s geographical catalog [24].

This research was governed by ethical aspects of Resolution 8430 of 1993 by the Ministry of Health, which classifies it without risk in its article 11 [25]. It also complies with Legislation 1581 of *habeas data* of 2012 and its Regulatory decree 1317 of 2013 [26,27].

Being an anonymized database, guarantees not identifying and individualizing cases, thus, safeguarding the right to personal, family and good name privacy, according to article 15 of Colombia’s Political Constitution [28].

For information processing, analysis, and presentation the study used the IBM SPSS 21® statistical software, Medellín MapGis massive geocoder developed by H&G under the ArcGIS Server/Java, ArcGIS 10®, Microsoft Excel and Word platforms, licensed to Universidad de Antioquia.

## Results

In Medellín, between 2010 and 2020, the INMLCF registered 2,988 deaths due to roadway incidents, 2,378 (79.6%) men and 610 (20.4%) women. Per mode of transport, those who died most were pedestrians, 1,423 (47.6%); followed by motorcyclists, 1,295 (43.3%); people travelling in automobiles, 142 (4.8%); and cyclists, 128 (4.3%). The age of the deceased ranged from 1 to 98 years, with a mean of 44 (standard deviation —SD— 21) and mode of 27; 50% were 40 years old or less, and 2,253 (75.4%) people were in the economically active population from 15 to 64 years of age.

By gender and age group, the highest mortality of pedestrians was registered in adults and over 45 years of age. The age group with greatest affectation was that of men between 60 and 74 years, with 295 (28.1%) deaths.

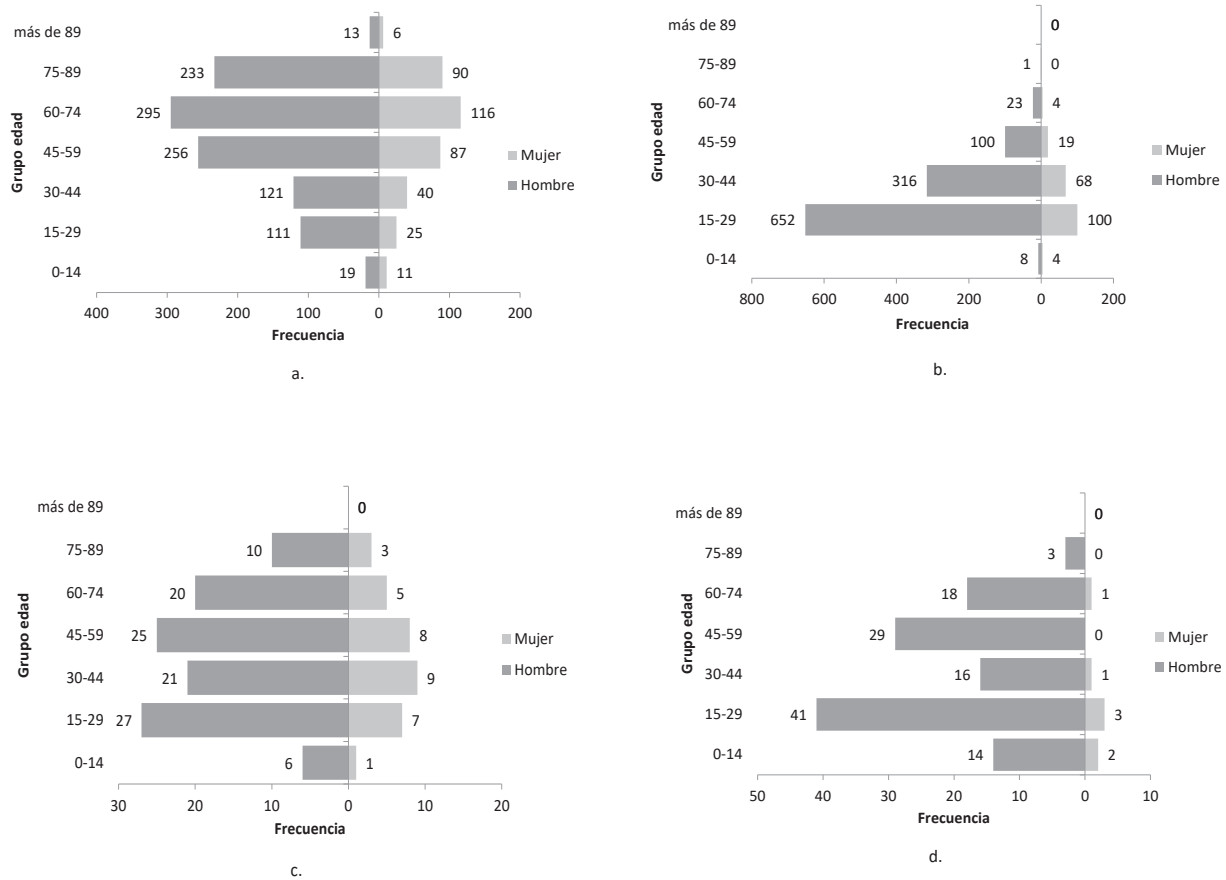
Male motorcyclists died more than female motorcyclists, with higher frequency in the age group from 15 to 29 years, with 652 (59.0%) registries, more than double the deaths occurring in the group of male motorcyclists from 30 to 44 years of age, where 316 (28.7%) deaths occurred. Men in automobiles died more than women, with the age group from 15 to 29 years of age having the highest mortality, with 27 (24.8%) deaths in total. For their part, male bicyclists men died mostly: 121 (95%) cases, with higher incidence in the age group from 15 to 29 years of age, with 41 (33.9%) deaths, followed by the age group 45-49 years, with 29 (24.0%) registries (Figure 1).

Overall, the people who died the most in roadway incidents in Medellín were of low academic level, 918 (30.7%) with basic primary, and 1,086 (36.3%) with basic secondary (Table 1).

By mode, the deceased pedestrians who reached the maximum basic primary were 630 (44.3%); motorcyclists who obtained basic secondary, 680 (52.5%); people in motor vehicles who died with secondary academic level, 51 (35.9%); and cyclists deceased with basic primary, 45 (35.2%). According to the victim’s marital status, those who died most were single, with 1,340 (44.8%) cases.

The most-common type of incident was getting run over, with 1,425 (47.7%) deaths. In this type of incident, 100% of pedestrians died; motorcyclists died more by colliding with another vehicle —812 (62.7%). In automobiles, the highest number of deaths was registered as fall by passenger, with 51 (35.9%) cases, while bicyclists died more when colliding with another vehicle, with 97 (75.8%) registries.

The year with the highest mortality was 2013, with 310 (10.4%) deaths. Pedestrians died more in 2010, with 177 (12.4%) registries; motorcyclists, in 2011, with 136 (10.5%) deaths; in 2011, 22 (15.5%) died in automobi-



**Figure 1.** Distribution of mortality due to roadway incident in age group, gender and mode, Medellín, 2010-2020. a. Pedestrians; b. motorcyclists; c. motorists; d. cyclists.

Source: Elaborated by the authors.

les, and bicyclists, in 2017 and 2019, had an equal number of deaths, 14 (10.9%), per year.

Between 2010 and 2020, by commune of incident occurrence, the highest roadway mortality was in La Candelaria, with 684 (22.9%) deaths. In this commune, roadway mortality, according to mode, had the following distribution: 458 (32.2%) pedestrians, 186 (14.4%) motorcyclists, 19 (13.4%) motorists, and 21 (16.4%) bicyclists. The townships of the city added 233 (7.8%) deaths; San Cristóbal had the highest mortality, with 80 (2.7%) deaths, and Altavista had the lowest, with 17 (0.6%).

The most-frequent injury was poly-traumatism; suffered by pedestrians and motorcyclists in percentages equal to or above 60%. The highest percentages of lesions in all modes of transport were recorded in the head, skull, and thorax, with high frequency of this injury in pedestrians and motorcyclists. Lesions to the face, neck, and upper limbs were manifested in lower proportion (Figure 2).

During the analysis period, there was a loss of 98,787 potential years of life due to roadway incidents, with an average of 8,981 PYLL per year, and a rate of 398 PYLL for every 100,000 inhabitants. The in which the most years of life were lost was 2011 (Table 2).

Motorcyclists lost the most years, with 58,505 in total (IPYLL =  $236 \times 100,000$  inhabitants), followed by 30,569 years lost by pedestrians (IPYLL =  $123 \times 100,000$  inhabitants). Cyclists lost 5,101 years (IPYLL =  $20 \times 100,000$  inhabitants), and people automobiles, 4,613 (IPYLL =  $19 \times 100,000$  inhabitants).

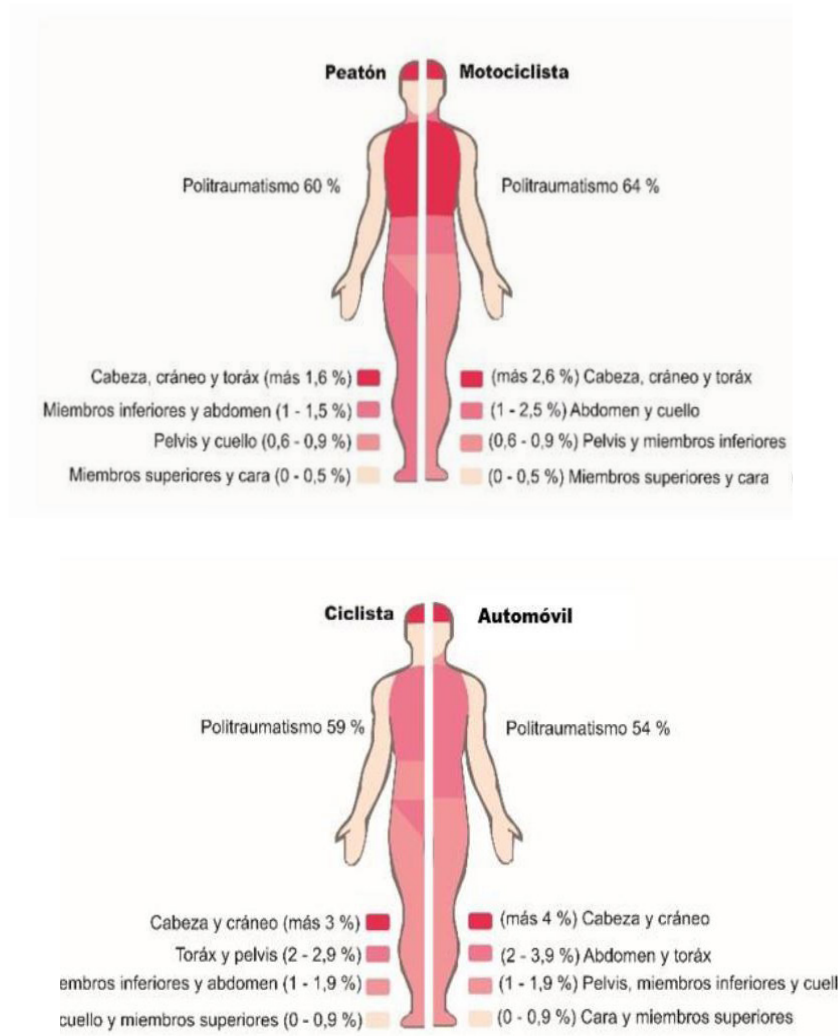
Male motorcyclists lost 46,178 potential years of life, and pedestrians, 20,456; in women, motorcyclists and pedestrians lost 9,409 and 1,174 potential years of life, respectively.

The roads with greater concentration of roadway deaths for pedestrians were: *Autopista norte*, Guayabal avenue, San Juan street, and Carrera 80; in communes, La Candelaria, Buenos Aires, Manrique, and Aranjuez these evidenced high density. The Popular, San Javier,

**Table 1.** Sociodemographic characteristics of people dying in roadway incidents according to mode. Medellín, 2010-2020.

	Variable	Mode				Total (%)
		Pedestrian (%)	Motorcyclist (%)	Automobile (%)	Cyclist (%)	
Gender	Male	1,048 (73.6)	1,100 (84.9)	109 (76.8)	121 (94.5)	2,378 (79.6)
	Female	375 (26.4)	195 (15.1)	33 (23.2)	7 (5.5)	610 (20.4)
Marital status	Single	483 (33.9)	731 (56.5)	55 (38.7)	71 (55.5)	1,340 (44.8)
	Married	387 (27.2)	175 (13.5)	41 (28.9)	26 (20.3)	629 (21.1)
	Common-law	175 (12.3)	293 (22.6)	28 (19.7)	12 (9.4)	508 (17.0)
	Widowed	135 (9.5)	5 (0.4)	6 (4.2)	3 (2.3)	149 (5.0)
	Separated, divorced	51 (3.6)	25 (1.9)	3 (2.1)	2 (1.6)	81 (2.7)
	Without information	192 (13.5)	66 (5.1)	9 (6.4)	14 (10.9)	281 (9.4)
	Academic level	Basic primary	630 (44.3)	197 (15.2)	46 (32.4)	45 (35.2)
Basic secondary		314 (22.0)	680 (52.5)	51 (35.9)	41 (32.0)	1,086 (36.4)
Technical/technological		24 (1.7)	127 (9.8)	9 (6.3)	7 (5.5)	167 (5.6)
Specialization		3 (0.2)	0(0)	2 (1.4)	0(0)	5 (0.2)
University		48 (3.4)	100 (7.7)	12 (8.5)	8 (6.2)	168 (5.6)
Doctorate		0(0)	1 (0.1)	0(0)	0(0)	1 (0.0)
None		65 (4.6)	6 (0.5)	3 (2.1)	1 (0.8)	75 (2.5)
Without information		339 (23.8)	184 (14.2)	19 (13.4)	26 (20.3)	568 (19.0)
Type of incident	Run over	1,423 (100)	2 (0.2)	0(0)	0(0)	1,425 (47.7)
	Collision with another vehicle	0(0)	812 (62.7)	36 (25.4)	97 (75.8)	945 (31.6)
	Collision with fixed or moving object	0(0)	358 (27.6)	23 (16.2)	22 (17.2)	403 (13.5)
	Fall of passenger	0(0)	69 (5.3)	51 (35.9)	6 (4.7)	126 (4.3)
	Overturn	0(0)	11 (0.8)	17 (12.0)	0(0)	28 (0.9)
	Fall of vehicle over a cliff	0(0)	6 (0.5)	6 (4.2)	3 (2.3)	15 (0.5)
	Fall from aircraft	0(0)	0(0)	6 (4.2)	0(0)	6 (0.2)
	Fire	0(0)	0(0)	1 (0.7)	0(0)	1 (0.0)
	Without information	0(0)	37 (2.9)	2 (1.4)	0(0)	38 (1.3)
Year	2010	177 (12.4)	90 (6.9)	19 (13.4)	12 (9.4)	298 (10.0)
	2011	141 (9.9)	136 (10.5)	22 (15.5)	9 (7.0)	308 (10.3)
	2012	122 (8.6)	132 (10.3)	15 (10.6)	10 (7.8)	279 (9.4)
	2013	147 (10.4)	135 (10.4)	17 (12.0)	11 (8.6)	310 (10.4)
	2014	140 (9.8)	126 (9.7)	15 (10.6)	12 (9.4)	293 (9.8)
	2015	147 (10.3)	108 (8.3)	9 (6.4)	10 (7.8)	274 (9.2)
	2016	128 (9.0)	127 (9.8)	10 (7.0)	13 (10.2)	278 (9.3)
	2017	114 (8.0)	125 (9.7)	11 (7.7)	14 (10.9)	264 (8.8)
	2018	115 (8.1)	108 (8.4)	6 (4.2)	11 (8.6)	240 (8.0)
	2019	111 (7.8)	113 (8.7)	11 (7.7)	14 (10.9)	249 (8.3)
	2020	81 (5.7)	95 (7.3)	7 (4.9)	12 (9.4)	195 (6.5)
	<i>Total</i>		1,423 (100)	1,295 (100)	142 (100)	128 (100)

Source: Elaborated by the authors.



**Figure 2.** Topographic diagnosis of the lesion due to roadway incident according to anatomical region. Medellín, 2010-2020.

Source: Elaborated by the authors.

Belén, and Laureles Estadio communes registered high and isolated concentrations of pedestrian deaths.

The zones with highest concentration of deaths of motorcyclists are registered from the north to the south of the city, specifically in the Medellín River roadway system, in addition to the central and northeastern zones, with extension toward the Buenos Aires commune and toward the township of Santa Elena (Figure 3).

City zones with roads with high vehicle capacity and development of high speeds, such as the north and south highways, and San Juan street, registered high density of roadway deaths in motorcyclists.

The highest density of deaths in bicyclists was found in the central zone and south of the city, in neighborhoods; like Alpujarra, Colombia, Cerro Nutibara,

San Bernardo, Juan Pablo Segundo, Trinidad, and Las Playas, neighborhoods belonging to the Guayabal, Polblado, Belén, and Candelaria communes.

In motorists, one of the areas with the highest density was similar to that of cyclists, finding this among the Alpujarra, Cerro Nutibara, Colombia, Santa Fe, Perpetuo Socorro, Conquistadores, and Villa Carlota neighborhoods, as well as in the center and south of the city. Another concentration zone of automobile deaths was evidenced on the north highway, *Carrera 64C*.

By determining the zones of influence in the river roadway system, it was found that the number of pedestrians deceased in a 500-meter radius was 420 (30.4%), and at 1,000 meters, 688 (49.8%). In motorcyclists, 467 (38.3%) died at 500 meters, and 636 (52.2%) at 1,000



**Table 2.** Potential years of life lost due to roadway incidents, according to modo and gender. Medellín, 2010-2020.

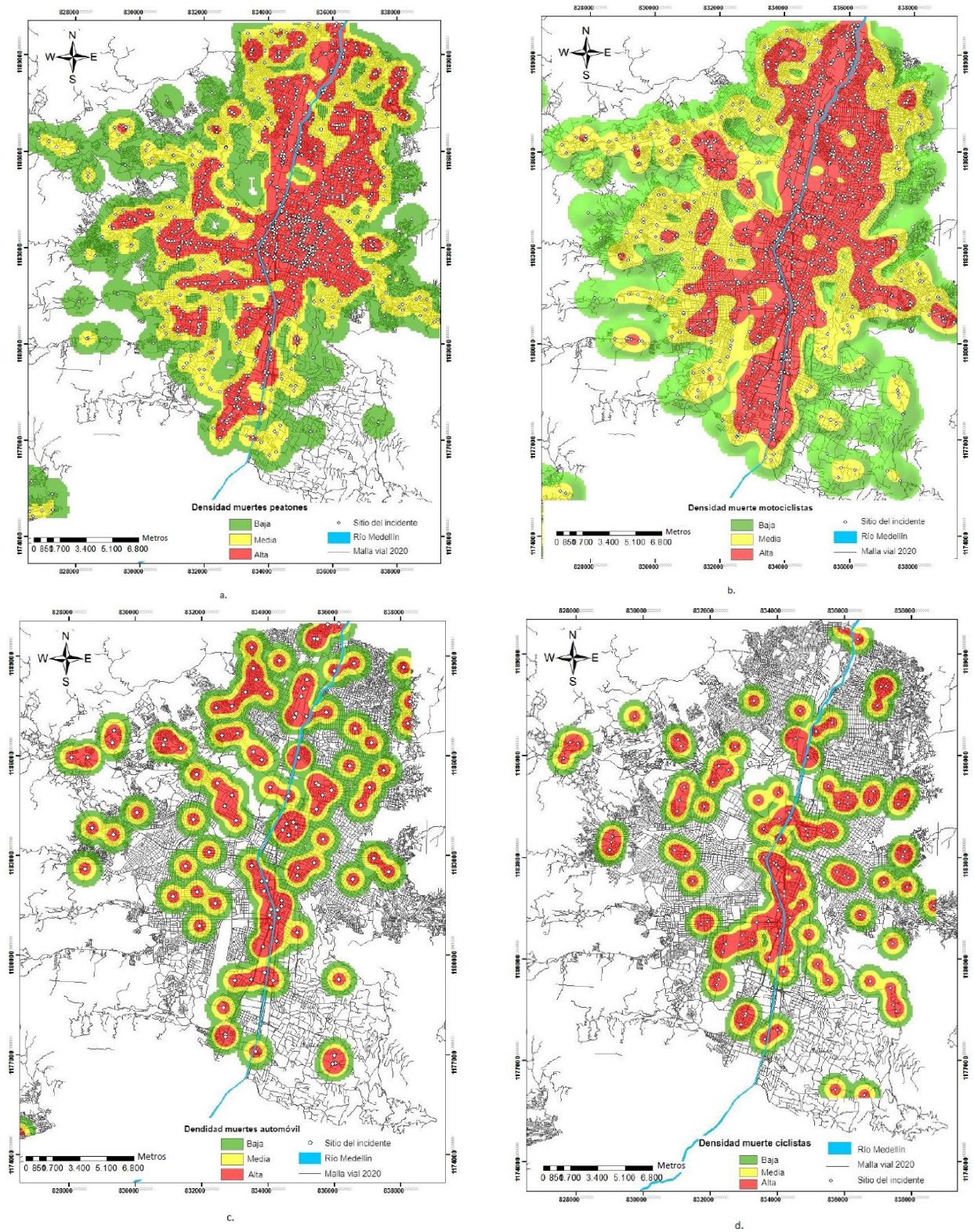
Year of death	Gender												Total				
	Male						Female						"Both sexes"				
	PYLL <sup>a</sup>	motorcyclist	PYLL <sup>b</sup> index	PYLL <sup>a</sup>	cyclist	PYLL <sup>b</sup> index	PYLL <sup>a</sup>	automobile	PYLL <sup>b</sup> index	PYLL <sup>a</sup>	pedestrian	PYLL <sup>b</sup> index	PYLL <sup>a</sup>	automobile	PYLL <sup>b</sup> index	PYLL <sup>a</sup>	PYLL <sup>b</sup> index
2010	2,804	281.7	262.9	475	47.7	408	41.0	1,108	97.1	894	78.3	0	182	15.9	8,931	421.4	
2011	5,192	514.4	2,165	149	14.7	773	76.6	824	71.5	912	79.0	36	87	7.5	10,777	502.4	
2012	5,002	488.8	1,633	355	34.7	175	17.1	701	60.2	801	68.7	0	138	11.9	9,311	429.1	
2013	4,825	465.6	2,197	332	32.1	404	39.0	726	61.7	830	70.6	117	97	8.2	10,085	459.7	
2014	4,602	438.9	2,228	564	53.8	201	19.2	770	64.8	883	74.2	0	156	26.4	10,053	453.2	
2015	3,648	343.9	2,382	327	30.8	119	11.2	1,095	91.1	613	51.0	0	156	12.9	8,796	392.2	
2016	4,305	400.8	1,736	434	40.4	315	29.3	1,083	88.9	766	62.9	62	47	3.8	9,198	405.2	
2017	4,232	388.6	1,261	513	47.1	217	19.9	924	74.8	805	65.2	17	2	0.1	8,397	364.9	
2018	4,157	375.5	1,462	292	26.4	183	16.6	657	52.3	736	58.6	125	12	1.0	7,997	341.9	
2019	4,152	366.4	1,581	437	38.6	246	21.7	833	64.9	774	60.4	0	139	10.9	8,585	359.3	
2020	3,260	282.0	1,194	508	43.9	181	15.7	689	52.8	479	36.7	0	0	0.0	6,658	273.6	
Total	46,178	393.6	20,456	4,386	37.4	3222	27.5	94,010	70.6	8,493	63.7	357	1,174	9.8	98,788	398.0	

<sup>a</sup> Regarding LEB by sex and general.

<sup>b</sup> Index per 100,000 inhabitants

PYLL: potential years of life lost.

Source: Elaborated by the authors.



**Figure 3.** Density of deaths due to roadway incidents according to mode. Medellín, 2010-2020. a. Pedestrians; b. motorcyclists; c. motorists; d. cyclists.

Source: Elaborated by the authors.

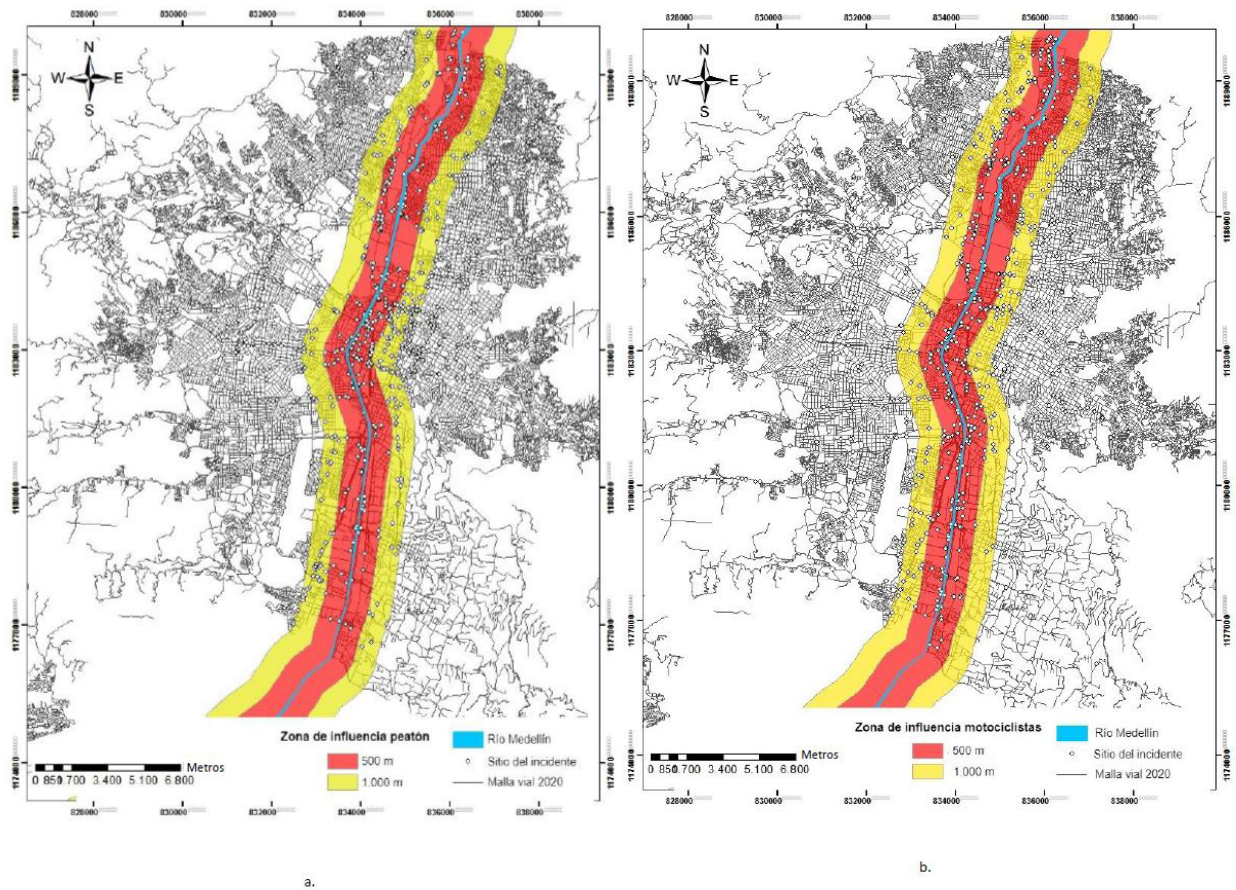


meters from the river roadway system. Motorists registered 37 (31.1%) mortal incidents at 500 meters, 53 (44.5%) at 1,000 meters, and of the 111 deaths in cyclists, 34 (30.6%) occurred within a 500-meter radius, and 48 (43.2%) at 1,000-meter distance (Figure 4).

## Discussion

Roadway deaths and injuries have been for decades an unattended problem, making mobility in urban centers of Latin America and the Caribbean a high-risk activity, where people in automobiles represented 34% of roadway deaths; motorcyclists, 23%; pedestrians,

22%, and cyclists, 3%; the remaining 18% were not specified [5]. Medellín evidenced improvement and progress regarding institutional management, cultural transformation, and adoption of the Vision Zero strategy to intervene risk factors; however, in 2020, the city was positioned in Colombia as having the highest number of roadway incidents, 30,450 in total, and was among those with the highest roadway mortalities, contributing, together with Cali, Cartagena, Barranquilla, and Villavicencio, 50% of the country's deaths, 1,580 deceased in diverse modes of transport (pedestrian, motorcycle, automobile, and bicycle) [6].



**Figure 4.** Roadway deaths by mode and zone of influence of the river roadway system. Medellín, 2010-2020. a. Pedestrians; b. motorcyclists; c. motorists; d. cyclists.

Source: Elaborated by the authors.

In Bogotá, 172 pedestrians died in 2021, where traveling on foot became the second mode of roadway risk, with 38% of mortality after those who traveled by motorcycle. In Medellín, pedestrians deceased represented 48% of roadway mortalities, with higher frequency of deaths in adult individuals, indicating that with older age, the risk of dying due to roadway incidents when walking increases. These results are similar to those of other studies, where adults over 65 years of age were involved in 21% of all incidents in pedestrians, and have higher relative risk of suffering serious injuries, of admission to critical care and fatality, than younger pedestrians [6,29,30].

Motorcyclists accumulated 43% of mortality and, contrary to that occurring with pedestrians, in this modality the deceased were, mostly youth from 15 to 29 years of age, results consistent with what was reported by the INMLCF and Colombia's National Agency on Roadway Safety, where young males, motorcyclists, contributed the highest number of deaths, and in 2020, cities, like Bogotá and Cali, registered 147 and 131 deaths of motorcyclists, respectively, which were mostly young males of productive age [6].

The results also show that more men who travel by bicycle die. The hypotheses may indicate that women feel insecure by using this mode of transport, do not like it, assume less behaviors of risk, or could be explained by greater perception of risk by women, which lead them to choose routes with lower density of vehicles, or they are simply more cautious when traveling [31,32].

Getting around Medellín by car is not a lower risk activity; This was attributed, in the last decade, to 142 deaths. In 2020, in Colombia, 73,987 automobiles were involved in roadway incidents, a situation materialized not only because of the type of incident, but also because of the age of the vehicular fleet and because many unsafe vehicles circulate daily, as they are built with low standards, without safety features and which are commercialized in the continent due to lack of a serious automotive policy, that mistakenly seeks to sell unsafe vehicles at higher costs than a safe latest generation vehicle, together with the complicity of local governments.

Moving around safely is a matter of rights, protected by the Colombian Political Constitution [33,34]. But, like many rights, this is also violated, with more consequences and greater inequality in people from low socioeconomic levels, with less education and lower purchasing power, the most vulnerable in society [35]; association pattern consistent with that obtained in this study, where poor people and people of low sociocultural level are those who died the most during the period observed.

The citizen claim to reduce roadway deaths and injuries is evident, as well as the intention of state investment to improve roadway safety indicators that re-

duce mortality [36]. These actions demand resources and require knowledge, management, organizational structure, leadership in mobility with Vision Zero approach and autonomy to make decisions that may be unpopular, which touch on constitutional limits, but, like everything, their avoidance is a collective right that must prevail in a social State, where the life and well-being of the community is above any interest [36].

Other works have estimated the difference of roadway mortality by sex, where young men have a greater risk of incident; this risk persists as age increases and they acquire more driving experience. Women have a lower risk of incident, but the risk of suffering lesions and hospitalization is greater [37]. These data agree with the findings of this research, where men die in higher proportion than women and in all modes of transport. These differences in risk of incident according to sex propose the need to understand how sex contributes to the perception of risk and how it is assumed without considering its consequences.

With respect to the number of PYLL, the contribution of the male sex was majority, almost four times compared to women. The total of PYLL in economically active age was 87,365 years, equivalent to 88% of the total of PYLL. Motorcyclists, although dying less than pedestrians, were the ones who stopped living the most years. Other works that have also estimated PYLL due to roadway incidents and their social impact by applying a broader perspective are coherent with the conclusions and results of this study, which reaffirms that by sex and mode of transport, men and motorcyclists die younger [6,38].

Prior studies in Medellín have provided evidence about the concentration of roadway deaths and injuries in the city, showing results similar to the findings, where zones of greater concentration of roadway deaths for pedestrians were the central eastern and northeastern communes; through specific points, North highway, San Juan street, and *Carrera 80*, had the greatest concentration [39].

The roads near the Medellín River, or incorrectly called "highways", which make up the road system adjacent to the river, form a strategic corridor with a high flow of vehicles that must cross the city to communicate with other municipalities in the metropolitan area, or even beyond it for the transport of goods and passengers. Like the river, these roads traverse the city from north to south, providing the quickest access to this end. Although other points of the city have high incidence of deaths of motorcyclists, when they ride through other roads, the probability of dying is higher, a fact related with the roadway design, excess speed, poor use of protection elements, and higher interaction of vehicles [23]. Therefore, managing speed and intervening in risk factors becomes essential to save lives, improve the city's sustainability, and counte-

tract negative effects on health and environment, as proposed by the Vision Zero strategy [8].

Evident, during the last decade, is the increased use of bicycles, beneficial due to the environmental, economic, and health impact, but challenging due to the lack of cycle routes and maintenance of existing ones, a situation that causes motorized and non-motorized users to share the road, which can increase and equalize the number of deaths of bicyclists with other roadway users.

Ambitious projects, like the north-south cycle route will encourage massive use of bicycles; nevertheless, if implemented without adequate maintenance and the safety of its users, soon it will be forgotten, underused, and appropriated for other uses.

The program "The future city" must privilege alternative and active means of mobility, which discourage using private vehicles and promote health from all settings.

Environments where greater progress is evident in roadway safety is attributed to improvements in legislation and intervention of key risk factors [34], like updating speed limits, avoiding the consumption of intoxicating beverages, promoting seat belt use, wearing helmets in those travelling on motorcycles, implementing child restraint systems; creating safer infrastructure, like sidewalks and special lanes for cyclists and motorcyclists, as well as issuing regulations for the entry of safe vehicles into the country manufactured with high safety standards and features, such as electronic control and advanced braking [34].

Consensus exists in the city that among all the approaches to improve roadway safety is the inclusion of Vision Zero as a strategy, which permits managing mobility processes based on the pillars of Life, Victims, Speed, Roads, and Vehicles. In addition, it seeks to provide comprehensive care to the phenomenon and its victims, with social reintegration, psychological care, and restitution of rights, and not only at the moment of the incident. There is also citizen, academic and institutional interest for local governments to strengthen legislation on the subject, making Vision Zero a State policy and not a campaign or program of local leaders [8,9,40].

## Conclusions

In conclusion, motorcyclists died younger and contributed the highest number of PYLL in roadway deaths of Medellín, while pedestrians died more during adult age.

Poly-traumatism is constant in deaths of all roadway users, but lesions in the head, skull, and thorax are more lethal when motorcyclists or pedestrians suffer them.

Walking in the city center is a risk activity crossed by cultural, contextual, and safety factors and land use by other activities, except that of walking. The center, as the axis and driving force of the city's development,

must be thought of as a zone of protection of the life of all living beings, with intervention on social determinants of health that results in healthier environments.

The river roadway system is made up of roads with high vehicular flow, but motorcyclists have the highest risk of exposure to dying, which can be increased by excess speed, not using protection elements, greater interaction of vehicles and road capacity.

## Study limitations

The study's limitations are related with the selection of the LEB for Colombia as the limit value to calculate the PYLL, given that it restricts international comparison, but favors local comparison. Also, the total data shows the record of cases captured by the INMLCE, a situation that may be different from that stated by the total deaths reported by DANE.

## Funding source

Inter-administrative contract N.º 4600090152 between the Secretariat of Mobility of Medellín and the National Faculty of Public Health at Universidad de Antioquia, for 2021.

## Acknowledgments

To the Secretariat of Mobility, the Unit of Cultural and Educational Transformation, and the Observatory of Mobility of Medellín for propitiating spaces for analysis and transfer of knowledge; to the National Institute of Legal Medicine and Forensic Sciences, for access to the information, and to the research groups on Management and Public Policies, and Epidemiology of the National Faculty of Public Health, Universidad de Antioquia.

## Declaration of conflict of interest

None declared by the authors.

## Declaration of authorship

*Edwin Salazar*: idea of the study, acquisition of the database, design of the research work, analysis and interpretation de results; drafting of the manuscript, critical review of the contents e intervention in the approval of the final version for publication.

*Gustavo Cabrera*: idea del study, analysis and interpretation de results, drafting of the manuscript, critical review of the contents and intervention in the approval of the final version for publication.



## Declaration of authors' responsibility

It is declared that the points of view expressed are those of the authors and not of the institutions where they work.

## Referencias

- Organización Mundial de la Salud. Declaración de Estocolmo Tercera Conferencia Ministerial Mundial sobre Seguridad Vial: Alcanzar los objetivos mundiales para 2030 [internet]; 2020 [citado 2021 ago. 28]. Disponible en: <https://www.roadssafetysweden.com/contentassets/b37f0951c837443eb9661668d5be439e/stockholm-declaration-spanish.pdf>
- Organización de Naciones Unidas. Resolución A/RES/74/299. Mejoramiento de la seguridad vial en el mundo [internet]. 2020 sep. 24 [citado 2021 ago 28]. Disponible en: [https://contralaviolenciavial.org/uploads/A\\_RES\\_74\\_299\\_S.pdf](https://contralaviolenciavial.org/uploads/A_RES_74_299_S.pdf)
- Organización Mundial de la Salud. Traumatismos causados por el tránsito [internet]. 2021, junio 21 [citado 2021 ago. 9]. Disponible en: <https://www.who.int/es/news-room/fact-sheets/detail/road-traffic-injuries>
- Yannis G, Nikolaou D, Laiou A, et al. Vulnerable road users: Cross-cultural perspectives on performance and attitudes. *IATSS Research*. 2020;44(3):220-9. DOI: <https://doi.org/10.1016/j.iatssr.2020.08.006>
- World Health Organization. Global status report on road safety 2018. Geneva: OMS; 2018.
- Colombia, Ministerio de Salud y Protección Social, Agencia Nacional de Seguridad Vial (MSPS-ANSV). Anuario Nacional de siniestralidad vial Colombia 2019. Bogotá: MSPS-ANSV; 2020.
- Instituto Nacional de Medicina Legal y Ciencias Forenses. Forensis 2019. Serie de Informes Técnicos Bogotá: Imprenta Nacional; 2019.
- Secretaría de Movilidad de Medellín. ¿Qué es Visión Cero? [internet]; 2021 [citado 2021 jun. 26]. Disponible en: <https://visionceromedellin.co/?playlist=cba060b&video=828a0309>
- Alcaldía de Medellín. Proyecto de acuerdo Plan de Desarrollo Medellín Futuro 2020-2023 [internet] 2020 [Consultado 2021 ago. 15]. Disponible en: [https://www.medellin.gov.co/irj/go/km/docs/peccdesign/medellin/Temas/PlanDesarrollo/Publicaciones/Shared%20Content/Documentos/2020/DocumentoFinal\\_PlanDesarrolloMedellin2020-2023\\_MedellinFuturo.pdf](https://www.medellin.gov.co/irj/go/km/docs/peccdesign/medellin/Temas/PlanDesarrollo/Publicaciones/Shared%20Content/Documentos/2020/DocumentoFinal_PlanDesarrolloMedellin2020-2023_MedellinFuturo.pdf)
- Naciones Unidas, Comisión de búsqueda de personas desaparecidas. *Registro nacional de desaparecidos* [internet]; 2007 [citado 2021 jul. 10]. Disponible en: [https://tbinternet.ohchr.org/Treaties/CED/Shared%20Documents/COL/INT\\_CED\\_ADR\\_COL\\_22518\\_S.pdf](https://tbinternet.ohchr.org/Treaties/CED/Shared%20Documents/COL/INT_CED_ADR_COL_22518_S.pdf)
- Instituto Nacional de Medicina Legal y Ciencias Forenses. Comisión de Búsqueda de Personas Desaparecidas, Registro Nacional de Desaparecidos [Internet] [2012 [citado 2021 jul. 10]. Disponible en: <https://www.medicinalegal.gov.co/documents/20143/40466/10.+Cartilla-Registro+Nacional+de+Desaparecidos.pdf>
- Pan American Health Organization. Techniques to measure the impact of mortality: Years of potential life lost. *Epidemiological Bulletin* [internet]. 2003 [citado 2021 jul. 10]; 24(2):1-4. Disponible en: [https://www3.paho.org/english/dd/ais/EB\\_v24n2.pdf](https://www3.paho.org/english/dd/ais/EB_v24n2.pdf)
- Martínez R, Soliz P, et al. Años de vida perdidos por muerte prematura: una medida versátil y abarcadora para el monitoreo de la mortalidad por enfermedades no transmisibles. *Int J Epidemiol*. [internet]. 2019 [citado 2021 jul. 10]; 48(4):1-10. <https://iris.paho.org/bitstream/handle/10665.2/50476/v43eAPHA12019.pdf?sequence=3&isAllowed=y>
- Colombia, Ministerio de Salud y Protección Social. Análisis de situación de salud. Bogotá: Minsalud; 2016.
- Araya R, Gómez A. Estimación de los años de vida potencialmente perdidos por accidentes de tránsito donde está involucrado [sic] una motocicleta [internet]. s. f. [citado 2021 jul. 11]. Disponible en: [https://odd.ucr.ac.cr/sites/default/files/comportamiento-motocicletas/avpp\\_pib\\_motos\\_informe-final-2017.pdf](https://odd.ucr.ac.cr/sites/default/files/comportamiento-motocicletas/avpp_pib_motos_informe-final-2017.pdf)
- Departamento Administrativo Nacional de Estadística. Estimaciones del cambio demográfico [internet]. 2018 [citado 2021 jun. 26]. Disponible en: <https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/estimaciones-del-cambio-demografico>
- Vargas J, Horfán D. Proceso de geocodificación de direcciones en la ciudad de Medellín, una técnica determinística de georreferenciación de direcciones. *Ing. USBMed*. 2013;4(1):6-21. DOI: <https://doi.org/10.21500/20275846.278>
- ArcGIS for Desktop. ArcMap. Geocodificar una tabla de direcciones—Ayuda [internet]. 2016 [citado 2021 jun. 21]. Disponible en: <https://desktop.arcgis.com/es/arcmap/10.3/guide-books/geocoding/geocoding-a-table-of-addresses-about.htm>
- ArcGIS for Desktop. ArcMap. Cómo funciona la densidad kernel—Ayuda [internet]. 2016 [citado 2021 jun. 21]. Disponible en: <https://desktop.arcgis.com/es/arcmap/10.3/tools/spatial-analyst-toolbox/how-kernel-density-works.htm>
- ArcGIS for Desktop. ArcMap. Densidad kernel—Ayuda [internet]. [citado 2021 jun. 21]. Disponible en: <https://desktop.arcgis.com/es/arcmap/10.3/tools/spatial-analyst-toolbox/kernel-density.htm>
- ArcGIS Pro. Métodos de clasificación de datos—Nuevas características y mejoras que se han agregado en esta versión. | Documentación [internet]. [citado 2021 jun. 21]. Disponible en: <https://pro.arcgis.com/es/pro-app/latest/help/mapping/layer-properties/data-classification-methods.htm>
- Alonso D. Cómo generar un buffer con QGIS. *MappingGIS* [internet]. 2021 [citado 2021 may. 7]. Disponible en: <https://mappinggis.com/2021/02/como-generar-un-buffer-con-qgis/>
- Porrás S, Grisales H. Años potenciales de vida perdidos por incidentes viales de motociclistas, Medellín, 2009-2012: un análisis espacial por sitio de la ocurrencia. *Rev. Med. Risaralda*. 2017;23(1):22-29. DOI: <https://doi.org/10.22517/25395203.13881>
- Alcaldía de Medellín. Catálogo geográfico de Medellín [internet]. s. f. [citado 2021 jun. 26]. Disponible en: [https://www.medellin.gov.co/giscatalogacion/srv/spa/catalog.search#/search?facet.q=groupOwner%2F374&resultType=details&sortBy=relevance&fast=index&\\_content\\_type=json&from=1&to=100](https://www.medellin.gov.co/giscatalogacion/srv/spa/catalog.search#/search?facet.q=groupOwner%2F374&resultType=details&sortBy=relevance&fast=index&_content_type=json&from=1&to=100)
- Colombia, Ministerio de Salud y Protección Social. Resolución 8430. Por la cual se establecen las normas científicas, técnicas y administrativas para la investigación en salud (1993 oct. 4).
- Colombia. Congreso de la República. Ley Estatutaria 1581 de 2012 (Ley de habeas data), por la cual se dictan disposiciones generales para la protección de datos personales (2012 oct. 17).
- Colombia, Ministerio de Comercio, Industria y Turismo. Decreto 1317, por el cual se reglamenta parcialmente la Ley 1581 de 2012 (2013 jun. 27).
- Asamblea Nacional Constituyente, Constitución Política de Colombia. Artículo 15. Respeto, libertad y demás garantías consagradas en cuanto a la recolección, tratamiento y circulación de datos. Bogotá; 1991.

29. Rod J, Oviedo O, et al. Older adult pedestrian trauma: A systematic review, meta-analysis, and GRADE assessment of injury health outcomes from an aggregate study sample of 1 million pedestrians. *Accid Anal Prev.* 2021;152:2-18. DOI: <https://doi.org/10.1016/j.aap.2021.105970>
30. Hern S, Oxley J, Logan D. Older adults at increased risk as pedestrians in Victoria, Australia: An examination of crash characteristics and injury outcomes. *Traffic Inj. Prev.* 2015;16(2):161-7. DOI: <https://doi.org/10.1080/15389588.2015.1061662>
31. Olesen A, Osmann T, Hels T, et al. Single-bicycle crashes: An in-depth analysis of self-reported crashes and estimation of attributable hospital cost. *Accid Anal Prev.* 2021;161:101-8. DOI: <https://doi.org/10.1016/j.aap.2021.106353>
32. Martínez V, Jiménez E, Amezcua C, et al. Factores asociados al riesgo de provocar una colisión entre un ciclista y un peatón en España, 1993-2011. *Gac Sanit.* 2015;29(Supl. 1):10-15. DOI: <https://doi.org/10.1016/j.gaceta.2015.04.005>
33. Asamblea Nacional Constituyente, Constitución Política de Colombia. Bogotá; 1991.
34. World Health Organization. Global status report on road safety 2018 [internet]; 2018 [citado 2021 jul. 29]. Disponible en: <https://www.who.int/publications/i/item/9789241565684>
35. Cabrera G, Salazar E, et al. Discapacidad de origen vial en Medellín, Antioquia 2017: Estudio descriptivo. Medellín: Universidad de Antioquia, SITT Ingeniería Tránsito y Tecnología Cía., SAS; 2017.
36. Espinosa A, Cabrera G, Velásquez N. Epidemiología de incidentes viales en Medellín, Colombia, 2010-2015. *Rev. Fac. Nac. Salud Pública,* 2017;35(1):7-15. DOI: <https://doi.org/10.17533/udea.rfnsp.v35n1a02>
37. Cullen P, Möller H, Woodward M, et al. Are there sex differences in crash and crash-related injury between men and women? A 13-year cohort study of young drivers in Australia. *SSM - Pop Health.* 2021;14:1-9. DOI: <https://doi.org/10.1016/j.ssmph.2021.100816>
38. Gu J, Fei G, Meng Y, et al. Revised road traffic safety law and years of life lost due to traffic deaths in China, 2002-2019. *Accid Anal Prev.* 2021; 161:1-9. DOI: <https://doi.org/10.1016/j.aap.2021.106344>
39. Alcaldía de Medellín. Plan de Movilidad Segura Medellín 2013-2020. "Movilidad para la vida". Medellín: Secretaría de Movilidad; 2014.
40. Alcaldía de Medellín, Secretaría de Movilidad de Medellín. Plan integral Visión Cero 2021-2025. Medellín: Secretaría de Movilidad de Medellín; 2021.

