NEW INDICATORS FOR ROAD ACCIDENTS ANALYSIS: THE "COLLISION MATRIX" AND ROAD USERS' RISK PROFILES[1]

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Abstract. Road accidents are a complex issue, and for a comprehensive analysis of the data, it is often recommended to use new indicators and innovative approaches rather than relying solely on traditional methods.
In order to study the different features of all road users and their interactions, it is very important to relate the specific risk elements of the connections between users and vehicles on the road. The paper presents the new collision matrices, with reference to killed or injured involved, the information on the vehicle in collision with they had the crash, and the method used to build the new indicators.

1. Introduction

Today, an information bias persists due to the selection of appropriate denominators for calculating road accident rates. Analysts often use resident population or vehicle fleet size as a common proxy for those at risk, but these choices are not always suitable.

The adoption of the new collision matrices contributes to fill in a gap about the road accidents analysis and to provide a new point of view for the investigation.

The presented study, besides, helps to outline elements for road safety performance too, measured with the support of the Key Performance Indicators, provided by the 2030 Agenda, for the European Union Countries. The new method offers a multidimensional approach to the subject, with roads, vehicles and the human behaviours as key elements.

In addition, to more traditional mortality and injury rates and even with respect to the length of the roads, also new in the Istat dissemination product, the new "collision matrices" introduces an innovative element of the project.

They use an accurate technique designed to connect those killed (within 30 days) or injured in road accidents, whether drivers, passengers, or pedestrians, with the type of vehicle responsible for the collision during the crash.

[1] Marco Broccoli and Silvia Bruzzone edited paragraph 1; Silvia Bruzzone edited paragraphs 2 and 3; Marco Broccoli edited paragraphs 4 and 5, Marco Broccoli and Silvia Bruzzone edited paragraph 6.

2. The road accidents resulting in death or injuries survey

The survey on road accidents resulting in death (within 30 day) or injury carried out by the Italian National Institute of Statistics (Istat), with the cooperation of ACI (Automobile Club of Italy) and other local organisations, is an exhaustive and monthly based data collection, included in the National Statistical Programme. The Police authorities verbalise for administrative reason and collects for Istat and statistical purpose all road accidents involving at least a vehicle circulating on the national road net, resulting in death or injury (Council Decision n. 704 of 1993, of 30 November 1993)[2].

The detection unit is the single road accident resulting in death or injury; the period when the accident occurred refers to all information collected.

As regards the data flow, Istat adopted a flexible model, through the subscription of a Memorandum of understanding or special agreements signed with regions (NUTS2 level) and provinces (NUTS3 level). Main information collected are: date, time and location of the accident, type of road and surface, signals, weather conditions, type of accident (collision, investment, etc.), type of vehicles involved, causes of the accident.

3. The road accidents in Italy and in Europe: an overview on recent data

During 2023, a stabilization in mobility occurs, if compared to 2022, a year in which there was a clear increase in noticed movements compared to the most acute phases of the pandemic. Concerning road accidents, 2023 shows a small improvement in the number of fatalities compared to the previous year; however, there is an upward trend in accidents and injuries, although slightly.

In 2023, we count 3,039 deaths in road accidents in Italy (-3.8% compared to the previous year), 224,634 injuries (+0.5%), and 166,525 road accidents (+0.4%). The values are slightly higher than 2022 for accidents and injuries, but lower for fatalities. There is still a decrease compared to 2019 for accidents, fatalities, and injuries (respectively -3.3%, -4.2%, and -6.9% (Figure 1 and Table 1).

In 2023, fatalities increased for drivers of e-scooters, bicycles, and electric bicycles, they are stable for pedestrians, and decreased for other users. There were 1,332 fatalities among car occupants (-3.1%), 734 among motorcyclists (-6.0%), 68 among moped riders (-2.9%), 485 among pedestrians (0.0%). Among truck occupants, 112 deaths were recorded (-32.5%), while for bicycles and electric bicycles, the fatalities were 212, an increase compared to 2022 when there were 205 (+3.4%). Injuries also increased among users of electric scooters (counted since 2020): road accidents involving them rose from

[2] Link to Decision EC 704/93

2,929 in 2022 to 3,365 in 2023, injuries from 2,787 to 3,195, while deaths (within 30 days) were 21 (in 2022 there were 16).

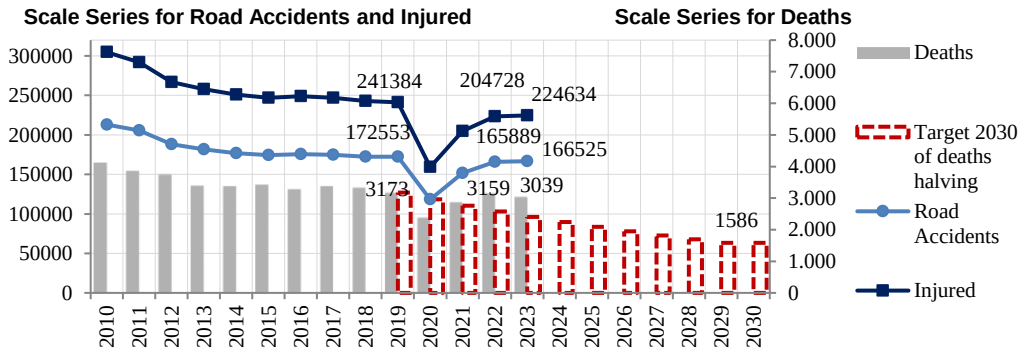
On urban roads, motorways and rural roads, road accidents and injuries are slightly up or stable compared to 2022, with values still all falling compared to the reference year 2019. The number of fatalities fell in comparison with 2022 in all road areas, with a substantial drop, in particular, on motorways (-19.0 per cent); on urban roads, the decrease was 0.3 per cent, on rural roads 3.9 per cent.

The most frequent types of incorrect driving behaviour are distraction, failure to yield right of way and speeding. The three groups together account for 36.5% of cases (80,057), a value that has remained stable over time.

Driving too fast is the most sanctioned behaviour after prohibited stop, parking, and accounts for 37% of all traffic offences. Sanctions for failure to use seat belts and child restraint systems fell slightly, while those for failure to wear a helmet rose sharply. The number of penalties for improper use of devices in the car remains high, and penalties for driving under the influence of alcohol are on the rise, especially the high proportion from local police forces.

The car market shows a growth in 2023: first registrations of passenger's cars increased by 18.4 % compared to 2022. On the motorway network, the annual average vehicle journeys shows a growth of 3.8% compared to 2022 and an increase compared to 2019, recording a maximum, in absolute terms for total journeys, which exceed 86.7 billion vehicles per km.

Figure 1 – *Road Accidents resulting in death or injury, deaths and injured. Years 2010-2023. (Absolute values).*



Source: Istat Survey on Road Accidents resulting in death or injury.

Table 1 - *Road accidents, deaths and injured persons. Years 2001, 2010-2023 (absolute values, deaths per million and percentage change).*

YEARS	**Road accidents** (a)	**Deaths**	**Injured**	**Deaths per million inhabitants** (b)	**Deaths yearly % change**	**Deaths % change vs 2001** (c)	**Deaths % change vs 2010** (c)
2001	263,100	7,096	373,286	124.5	-	-	-
2010	212,997	4,114	304,720	68.8	-	-42.0	-
2011	205,638	3,860	292,019	64.3	-6.2	-45.6	-6.2
2012	188,228	3,753	266,864	62.4	-2.8	-47.1	-8.8
2013	181,660	3,401	258,093	56.4	-9.4	-52.1	-17.3
2014	177,031	3,381	251,147	56.1	-0.6	-52.4	-17.8
2015	174,539	3,428	246,920	56.9	+1.4	-51.7	-16.7
2016	175,791	3,283	249,175	54.6	-4.2	-53.7	-20.2
2017	174,933	3,378	246,750	56.3	+2.9	-52.4	-17.9
2018	172,553	3,334	242.919	55.7	-1.3	-53.0	-19.0
2019	172,183	3,173	241,384	53.1	-4.8	-55.3	-22.9
2020	118,298	2,395	159,249	40.3	-24.5	-66.2	-41.8
2021	151,875	2,875	204,728	48.6	+20,0	-59.5	-30.1
2022	165,889	3,159	223,475	53.6	+9.9	-55.5	-23.2
2023	**166,525**	**3,039**	**224,634**	**51.5**	**-3.8**	**-57.2**	**-26.1**

(a) Road accident resulting in deaths (within the 30th day) or injuries represent the event that involves at least a vehicle circulating on the national road net.
(b) Deaths out of resident population (per 1,000,000).
(c) The percentage changes of the number of deaths is calculated as $((D^{t}/D^{t-1 \text{ or } 2001 \text{ or } 2010}) - 1)*100$

There were 20,365 fatalities on the roads of the EU27 in 2023, compared to 20,685 in 2022, 22,761 in 2019 and about 30,000 in 2010. The decrease in 2023 was very small and amounted to -1.5% on the previous year, while there was a decrease of 10.5% compared to 2019.

For the decade 2021-2030, the European targets on road safety recommend the halving the number of deaths and serious injuries by 2030 compared to the benchmark year (2019) and the monitoring of specific performance indicators, Key Performance Indicators[3]. The road death rate (deaths per million inhabitants) stands at 45.4 in the EU27 and 51.5 in Italy. Our country remains in 19th place in the European ranking, tied with Poland (European Transport Safety Council, 2024).

[3] The European Commission is in charge of coordinating the work of the EU27 countries for the production of the key performance indicators (8 different indicators on the topics: infrastructure, vehicles, road infrastructure, post-accident care). Each country will provide between one and eight national KPIs, comparable and with the minimum methodological requirements decreed by the European Commission (TRENDLINE project).

4. Collision Matrices: the methodology used

The "collision matrices" represent the original element of the project, calculated by road type and other crucial features. The matrix structure consist in an accurate technique, aimed to put in connections all persons killed (within 30 days) or injured in road accidents, drivers and passengers, or pedestrian and the vehicle type, responsible of the collision during the crash.

The road accident indicators based on collision matrices make it possible to outline risk profiles for road users and to highlight differences by type of road, urban and rural, by geographical zone of accident event and by gender and age of users involved.

The project was born following a format used by the European Commission[4], implementing a national variation. The Italian research provides, in fact, an updated and enriched version, in respect to the European Commission proposal.

The Collision Matrix proposed by EU include data with coverage of fatalities in single-vehicle crashes and crashes involving one or more traffic units. For most fatal crashes, only one other vehicle is involved in the crash. For multi-vehicle crashes, the "main vehicle" is the heaviest of the vehicles involved, as this tends to be responsible for the most serious consequences. As results, the figures in each column likely underestimate the number of cases a particular vehicle was involved in a crash (Source: EU CARE Database).

Concerning the Italian version, the values within the cells of the matrix represent, as an added value, a partition of total cases (killed or injured), developing an algorithm combining and permuting all vehicles involved in the accidents and all the crashing interaction between vehicles and other vehicles or pedestrians. Another customisation implemented by the Italian researchers, in the matrix Italian version is the introduction of two new types of vehicle: E-bike and E-scooters.

The algorithm used to build the collision matrix includes the implementation of an iterative process that considers in sequence some steps:

1) Road accidents involving a single vehicle (single vehicle and all pedestrians);

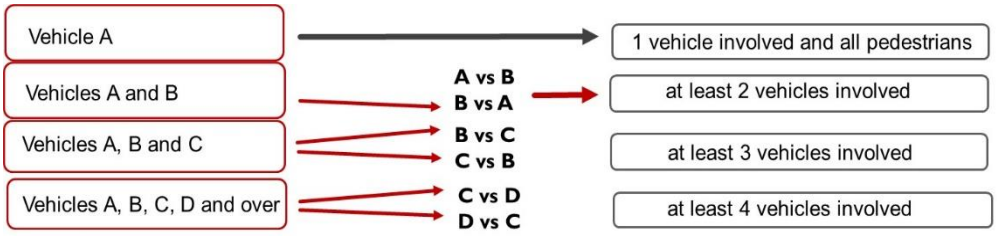
2) Road accidents involving at least two vehicles (vehicle A and B), making comparisons between the first two vehicles A vs B and B vs A;

3) Road accidents involving at least three vehicles (vehicles A, B and C), making comparisons between vehicles B vs C and C vs B, considering that the comparisons vs vehicle A have already been done.

The next steps follow, in an iterative mode, the same process (Figure 2).

[4] European Commission: 2023 figures show stalling progress in reducing road fatalities in too many countries - European Commission (europa.eu)

Figure 2 - *General scheme of the iterative procedure for collision matrices processing.*



Source: Istat processing

5. Collision Matrices: main results

The collision matrices produced contain data for a set of years, in time series, considering the main benchmarks years for the last road safety decades (2001, 2010 and 2019) and the most recent data too (2022 and 2023)[5].

They refer to fatalities and injuries for drivers, passengers or pedestrians and detailed for urban and rural areas. The collision matrix includes, as an innovative analysis element, the information on the mortality or harmfulness risk (as a proxy) for the different user's categories. The tables contain the absolute number for the cross-referencing of the matrix cells, the row percentage values and the column percentage values. The reading key, by the percentage values information too, is useful to understand immediately the weight of each category out of the total.

The analysis of the main and most recent data for 2023 shows interesting results.

Concerning mortality data, for the most vulnerable users, the drivers of electric bicycles and scooters collide mainly against passenger cars or they are involved in single vehicles accidents. Powered two-wheelers have a high number of fatal accidents in collisions with passenger cars, light commercial vehicles and as single vehicles too. Pedestrians present a higher mortality risk than other users when they collide with passenger cars or with heavy good vehicles. Passenger's cars users crashes mainly with other cars or as single vehicles. Heavy Good Vehicles collide against other heavy good vehicles, passenger's cars, and in single vehicle accidents (Table 2, 3 and 4).

[5] Istat Road accidents in Italy. Year 2023 (Appendices) https://www.istat.it/en/press-release/road-accidents-2023/

Table 2 - *Collision matrix for road accidents fatalities by road user and other vehicles involved. Year 2023 (absolute values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	4	2	0	4	33	353	37	28	14	10	0	**485**
Bicycles	6	0	0	0	9	116	18	14	4	7	26	**200**
E-bikes	0	0	0	1	1	7	1	0	0	0	2	**12**
E-scooters	0	0	0	0	2	6	0	1	0	0	12	**21**
Mopeds	0	0	0	3	2	29	4	1	0	4	25	**68**
Motor-bikes	2	0	1	0	33	375	50	23	6	4	240	**734**
Passengers cars	1	0	0	4	4	532	68	123	15	21	564	**1,332**
Lorries (< 3,5 t)	0	0	0	0	0	9	5	8	2	0	18	**42**
Heavy Good Vehicles (> 3,5 t)	0	0	0	0	0	11	2	27	5	0	25	**70**
Buses or Coach	0	0	0	0	0	0	0	5	0	0	23	**28**
Other vehicles	0	0	0	0	1	20	3	9	0	0	14	**47**
Total	**13**	**2**	**1**	**12**	**85**	**1,458**	**188**	**239**	**46**	**46**	**949**	**3,039**

Table 3 - *Collision matrix for road accidents fatalities by road user and other vehicles involved. Year 2023 (Row percentage values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	0.8	0.4	0.0	0.8	6.8	73.0	7.6	5.6	2.9	2.1	0.0	100.0
Bicycles	3.0	0.0	0.0	0.0	4.5	58.0	8.5	7.5	2.0	3.5	13.0	100.0
E-bikes	0.0	0.0	0.0	8.3	8.3	58.3	8.3	0.0	0.0	0.0	16.8	100.0
E-scooters	0.0	0.0	0.0	0.0	9.5	28.6	0.0	4.8	0.0	0.0	57.1	100.0
Mopeds	0.0	0.0	0.0	4.4	2.9	42.6	5.9	1.5	0.0	5.9	36.8	100.0
Motor-bikes	0.3	0.0	0.1	0.0	4.5	51.1	6.8	3.1	0.8	0.5	32.8	100.0
Passengers cars	0.1	0.0	0.0	0.3	0.3	39.9	5.1	9.2	1.1	1.6	42.4	100.0
Lorries (< 3,5 t)	0.0	0.0	0.0	0.0	0.0	21.4	11.9	19.0	4.8	0.0	42.9	100.0
Heavy Good Vehicles (> 3,5 t)	0.0	0.0	0.0	0.0	0.0	15.7	2.9	38.6	7.1	0.0	35.7	100.0
Buses or Coach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	82.1	100.0
Other vehicles	0.0	0.0	0.0	0.0	2.1	42.6	6.4	19.1	0.0	0.0	29.8	100.0
Total	0.4	0.1	0.0	0.4	2.8	48.0	6.2	7.9	1.5	1.5	31.2	100.0

Table 4 - *Collision matrix for road accidents fatalities by road user and other vehicles involved. Year 2023 (Column percentage values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	30.8	100.	0.0	33.3	38.8	24.2	19.7	11.7	30.4	21.7	0.0	16.0
Bicycles	46.2	0.0	0.0	0.0	10.6	8.0	9.6	5.9	8.7	15.2	2.7	6.6
E-bikes	0.0	0.0	0.0	8.3	1.2	0.5	0.5	0.0	0.0	0.0	0.2	0.4
E-scooters	0.0	0.0	0.0	0.0	2.4	0.4	0.0	0.4	0.0	0.0	1.3	0.7
Mopeds	0.0	0.0	0.0	25.0	2.4	2.0	2.1	0.4	0.0	8.7	2.6	2.2
Motor-bikes	15.4	0.0	100.	0.0	38.7	25.7	26.6	9.6	13.0	8.7	25.3	24.2
Passengers cars	7.6	0.0	0.0	33.2	4.7	36.4	36.1	51.5	32.7	45.7	59.5	43.8
Lorries (< 3,5 t)	0.0	0.0	0.0	0.0	0.0	0.6	2.7	3.3	4.3	0.0	1.9	1.4
Heavy Good Vehicles (> 3,5 t)	0.0	0.0	0.0	0.0	0.0	0.8	1.1	11.3	10.9	0.0	2.6	2.3
Buses or Coach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	2.4	0.9
Other vehicles	0.0	0.0	0.0	0.0	1.2	1.4	1.6	3.8	0.0	0.0	1.5	1.5
Total	100	100	100	100	100	100	100	100	100	100	100	100

As regards the vehicles involved in the collision, passengers' cars drivers are responsible, in total, mainly for other car occupants' deaths (36.4%), motorcyclists' fatalities (25.7%), and pedestrians (24.2%, 39% in urban area). Motorcyclists, instead, kill mainly, pedestrians (38.8%) and other motorcyclists (38.7%) (Table 4).

The analysis of collision matrices data for fatalities within urban areas shows a slightly different profile for users and the type of vehicles in collision with them enter during the crash, if compared with the total data or with rural roads information.

Cyclists, in fact, reach a percentage of collision with passengers' cars of 64.2%, while the value is 58% as whole and 51.1% on rural roads. Concerning e-scooters, the collision is more frequent within urban roads (14 deaths in 2023) than outside the built up areas (7 deaths in 2023). The collision outside the cities is mainly with passengers' cars (57.1%); inside the urban roads, the percentage is highest for accidents as single vehicles due to the loosing of control of the means of transportation (78.6%). A possible cause could be the condition of the surface of the road or the distraction or the misuse of the vehicle, without the respect of the rules of use. For motorcyclists, ever for crashes with passengers' cars, the percentage of collision rises to 54.1% from 51.1% as whole and 48.3 outside built up areas (Table 5, 6 and 7).

Table 5 - *Collision matrix for road accidents fatalities, within urban areas, by road user and other vehicles involved. Year 2023 (absolute values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	4	2	0	4	32	283	27	17	13	7	0	389
Bicycles	3	0	0	0	1	68	9	8	2	2	13	106
E-bikes	0	0	0	0	1	5	0	0	0	0	1	7
E-scooters	0	0	0	0	1	2	0	0	0	0	11	14
Mopeds	0	0	0	2	1	15	1	1	0	3	16	39
Motor-bikes	0	0	1	0	10	193	29	4	3	1	116	357
Passengers cars	1	0	0	1	2	149	16	9	6	4	203	391
Lorries (< 3,5 t)	0	0	0	0	0	2	1	0	1	0	5	9
Heavy Good Vehicles (> 3,5 t)	0	0	0	0	0	2	1	0	0	0	3	6
Buses or Coach	0	0	0	0	0	0	0	1	0	0	1	2
Other vehicles	0	0	0	0	1	6	1	0	0	0	1	9
Total	8	2	1	7	49	725	85	40	25	17	370	1,329

Table 6 - *Collision matrix for road accidents fatalities, within urban areas, by road user and other vehicles involved. Year 2023 (Row percentage values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	1.0	0.5	0.0	1.0	8.2	72.8	6.9	4.4	3.3	1.8	0.0	100.0
Bicycles	2.8	0.0	0.0	0.0	0.9	64.2	8.5	7.5	1.9	1.9	12.3	100.0
E-bikes	0.0	0.0	0.0	0.0	14.3	71.4	0.0	0.0	0.0	0.0	14.3	100.0
E-scooters	0.0	0.0	0.0	0.0	7.1	14.3	0.0	0.0	0.0	0.0	78.6	100.0
Mopeds	0.0	0.0	0.0	5.1	2.6	38.5	2.6	2.6	0.0	7.7	41.0	100.0
Motor-bikes	0.0	0.0	0.3	0.0	2.8	54.1	8.1	1.1	0.8	0.3	32.5	100.0
Passengers cars	0.3	0.0	0.0	0.3	0.5	38.1	4.1	2.3	1.5	1.0	51.9	100.0
Lorries (< 3,5 t)	0.0	0.0	0.0	0.0	0.0	22.2	11.1	0.0	11.1	0.0	55.6	100.0
Heavy Good Vehicles (> 3,5 t)	0.0	0.0	0.0	0.0	0.0	33.3	16.7	0.0	0.0	0.0	50.0	100.0
Buses or Coach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	50.0	100.0
Other vehicles	0.0	0.0	0.0	0.0	11.1	66.7	11.1	0.0	0.0	0.0	11.1	100.0
Total	0.6	0.2	0.1	0.5	3.7	54.6	6.4	3.0	1.9	1.3	27.8	100.0

Table 7 - *Collision matrix for road accidents fatalities, within urban areas, by road user and other vehicles involved. Year 2023 (Column percentage values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	50.0	100.	0.0	57.1	65.3	39.0	31.8	42.5	52.0	41.2	0.0	29.3
Bicycles	37.5	0.0	0.0	0.0	2.0	9.4	10.6	20.0	8.0	11.8	3.5	8.0
E-bikes	0.0	0.0	0.0	0.0	2.0	0.7	0.0	0.0	0.0	0.0	0.3	0.5
E-scooters	0.0	0.0	0.0	0.0	2.0	0.3	0.0	0.0	0.0	0.0	3.0	1.1
Mopeds	0.0	0.0	0.0	28.6	2.0	2.1	1.2	2.5	0.0	17.6	4.3	2.9
Motor-bikes	0.0	0.0	100.	0.0	20.4	26.6	34.1	10.0	12.0	5.9	31.4	26.9
Passengers cars	12.5	0.0	0.0	14.3	4.1	20.6	18.8	22.5	24.0	23.5	54.9	29.4
Lorries (< 3,5 t)	0.0	0.0	0.0	0.0	0.0	0.3	1.2	0.0	4.0	0.0	1.4	0.7
Heavy Good Vehicles (> 3,5 t)	0.0	0.0	0.0	0.0	0.0	0.3	1.2	0.0	0.0	0.0	0.8	0.5
Buses or Coach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.3	0.2
Other vehicles	0.0	0.0	0.0	0.0	2.0	0.8	1.2	0.0	0.0	0.0	0.3	0.7
Total	100	100	100	100	100	100	100	100	100	100	100	100

Injuries matrices shows similar results and profiles within and outside urban areas.

Finally, an interesting comparison consists in the time series collision matrices analysis too.

One of the most evidence emerged, for instance, is the increasing of the percentage of single vehicles accidents, in particular within built up areas. The percentage rises, in fact, since 38.3% in 2001 (Table 9) to 51.9% in 2023 (Table 6). In addition, drivers of lorries, classified as light commercial vehicles, shows a strong increase of single vehicle accidents, from 34.8% to 55.6%.

The specific increase could partly result from distractions caused by using smartphones or devices while driving, along with bad road conditions or speeding. Some studies (Matthews *et al.* 2019) deal with the strong connection between fatigue and distraction driving too, or between other activities done while driving, such as eating or drinking, and texting (Choudhary *et al.*, 2017; Gariazzo *et al*., 2018)). The rise in distractions often leads to road accidents for lorry drivers as well, especially in recent years, with the growing spread of e-commerce and delivery networks.

Table 8 - *Collision matrix for road accidents fatalities, within urban areas, by road user and other vehicles involved. Year 2001 (absolute values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	5	-	-	72	73	578	42	41	17	8	-	836
Bicycles	-	-	-	3	13	147	23	29	2	4	25	246
E-bikes	-	-	-	-	-	-	-	-	-	-	-	-
E-scooters	-	-	-	-	-	-	-	-	-	-	-	-
Mopeds	2	-	-	17	16	192	21	30	7	3	87	375
Motor-bikes	5	-	-	2	14	284	27	30	2	4	131	499
Passengers cars	6	-	-	15	18	560	78	85	25	8	494	1.289
Lorries (< 3,5 t)	-	-	-	1	1	17	3	8	-	-	16	46
Heavy Good Vehicles (> 3,5 t)	-	-	-	-	-	1	1	6	-	-	7	15
Buses or Coach	-	-	-	-	1	3	-	-	1	-	6	11
Other vehicles	-	-	-	-	1	21	1	2	-	-	9	34
Total	18	-	-	110	137	1.803	196	231	54	27	775	3.351

Table 9 - *Collision matrix for road accidents fatalities, within urban areas, by road user and other vehicles involved. Year 2001 (Row percentage values).*

	IN COLLISION WITH											
FATALITIES BY USER TYPE	**Bi-cycles**	**E-bikes**	**E-scooters**	**Mopeds**	**Motorbikes**	**Passengers cars**	**Lorries (< 3,5 t)**	**Heavy Good Vehicles (> 3,5 t)**	**Buses or Coach**	**Other vehicles**	**No other vehicle involved**	**Total**
Pedestrians	0,6	-	-	8,6	8,7	69,1	5,0	4,9	2,0	1,0	0,0	100,0
Bicycles	0,0	-	-	1,2	5,3	59,8	9,3	11,8	0,8	1,6	10,2	100,0
E-bikes	-	-	-	-	-	-	-	-	-	-	-	-
E-scooters	-	-	-	-	-	-	-	-	-	-	-	-
Mopeds	0,5	-	-	4,5	4,3	51,2	5,6	8,0	1,9	0,8	23,2	100,0
Motor-bikes	1,0	-	-	0,4	2,8	56,9	5,4	6,0	0,4	0,8	26,3	100,0
Passengers cars	0,5	-	-	1,2	1,4	43,4	6,1	6,6	1,9	0,6	38,3	100,0
Lorries (< 3,5 t)	0,0	-	-	2,2	2,2	37,0	6,5	17,4	0,0	0,0	34,8	100,0
Heavy Good Vehicles (> 3,5 t)	0,0	-	-	0,0	0,0	6,7	6,7	40,0	0,0	0,0	46,7	100,0
Buses or Coach	0,0	-	-	0,0	9,1	27,3	0,0	0,0	9,1	0,0	54,5	100,0
Other vehicles	0,0	-	-	0,0	2,9	61,8	2,9	5,9	0,0	0,0	26,5	100,0
Total	0,5	-	-	3,3	4,1	53,8	5,8	6,9	1,6	0,8	23,1	100,0

6. Conclusions

Collision matrices represent a new tool for analysing road accident data, allowing for the study of connections between road users—whether injured, killed, or hurt—and the vehicles they collided with, which are often responsible for the accident. The scientific community particularly values the analysis using two-way tables because it explains data clearly and straightforwardly, filling an existing information gap in the available tools. The generalization of collision matrices for the Italian model introduces two innovations: the inclusion of electric scooters and electric bicycles, and the calculation that allows for a data partitioning in the table, with marginal distributions that include all recorded cases of deaths and injuries, not just those involving the first two vehicles, as proposed by the European Commission.

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