



Fatality Patterns in Attica: A Multi-Method Study of Trends, Clusters & COVID-19 Disruptions

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INTRODUCTION AND OBJECTIVES

Road traffic fatalities represent a major public health and societal challenge, particularly in urban areas where exposure, infrastructure complexity, and transport diversity converge.

- WHO (2018): road crashes claim over 1.35 million lives and cause 50+ million injuries annually
- In 2020, Greece recorded 584 fatalities and ranked as the worst-performing EU member state on road traffic mortality (Stipdonk et al., 2025)
- The COVID-19 pandemic (declared March 2020) caused unprecedented disruptions in mobility, law enforcement, and road user behaviour
- The Safe System approach recognizes that while human error is inevitable, death and serious injury are not, it targets safe roads, vehicles, speeds, users, and post-crash care (OECD/ITF, 2020)

Objectives of this study:

1. Analyze road fatalities in Attica, Greece (2016–2022) using an integrated multi-method framework.
2. Identify fatality patterns, structural risk groups, and COVID-19 effects across user categories.
3. Support regional road safety monitoring aligned with Greece's 2030 Road Safety Strategy and Safe System principles.

BACKGROUND AND LITERATURE

Safe System Framework

The Safe System approach acknowledges that human error is inevitable but fatal outcomes are not, targeting roads, speeds, vehicles, and user behaviour holistically (OECD/ITF, 2020; Yiannis et al., 2023).

Trend & Cluster Analysis

Regression and ARIMA models have been used to detect long-term fatality trends (Yousefzadeh-Chabok et al., 2016; Folla et al., 2023). Hierarchical clustering has effectively revealed latent structure in crash data across driver risk profiles and causal factors (Parikh, 2021; Manasa et al., 2024; Hayashi et al., 2023).

COVID-19 Effects

Lockdowns reduced absolute fatalities but increased fatality rates on emptier roads (Wegman & Katrakazas, 2021). Greece-specific SARIMA models confirmed significant collision reductions during 2020 (Sekadakis et al., 2021), with lasting behavioural shifts observed post-pandemic (Ungureanu et al., 2024).

Gap: Few studies integrate all three approaches descriptive, clustering, and inferential, within a single regional framework.

Fig. 1. True annual total road fatalities in Attica (2016-2022)



METHODOLOGY AND DATA

Data Source

Data were obtained from the NTUA Road Safety Observatory (NRSO) and cover road fatalities in the Attica region, Greece, for 2016–2022. The dataset includes 18 disaggregated dimensions: road user type, age, gender, road type, geographic area, lighting conditions, number of vehicles involved, and weather. All analyses use fatality counts only, no exposure denominators (e.g. vehicle-km, population) were available.

Descriptive Analytics

Annual and categorical distributions were summarized using mean, standard deviation, min/max, and coefficient of variation. This identified key risk groups, persistent patterns, and temporal fluctuations across all 18 categories, and served as the input layer for subsequent analyses.

Hierarchical Cluster Analysis

Hierarchical agglomerative clustering was applied using Ward's linkage and Euclidean distance on standardized (z-score) values. Categories were treated as observations and years (2016–2022) as variables. The optimal cluster structure was determined through dendrogram inspection and visualized with a heatmap of standardized fatality values.

Pre-/Post-COVID Comparison

The study period was divided into Pre-COVID (2016–2019) and Post-COVID (2020–2022). Two-sample t-tests assuming unequal variances tested whether mean fatality counts differed significantly between periods (threshold: $p < 0.05$). Given the small number of annual observations, all findings are treated as exploratory evidence rather than causal conclusions.

Simple Linear Regression

A simple linear regression model was fitted per category, with year as the independent variable and fatality count as the dependent variable. The slope (β) indicates trend direction; R^2 measures the strength of the linear fit.

Table 1. Descriptive statistics of road fatalities by category, Attica (2016–2022)

Category	mean	std	min	max	variation_%
Children killed (0-14)	1.71	0.95	0.00	3.00	55.49
Cyclists killed	2.14	1.21	1.00	4.00	56.70
Moped riders killed	3.00	2.58	0.00	7.00	86.07
Women drivers killed	5.00	1.91	2.00	8.00	38.30
When raining	6.57	3.82	2.00	12.00	58.18
Non-national riders killed	8.57	2.99	4.00	13.00	34.91
Non-national drivers killed	11.86	2.97	8.00	16.00	25.03
On motorways	14.71	4.54	10.00	22.00	30.82
Young drivers killed (18-24)	14.71	3.25	11.00	19.00	22.10
Older drivers killed (65+)	17.86	5.21	13.00	26.00	29.18
Outside built-up areas	29.71	7.25	16.00	37.00	24.40
Pedestrians killed	44.43	11.94	30.00	63.00	26.88
Killed in single-vehicle crashes	55.00	6.68	46.00	64.00	12.15
During nighttime	72.29	8.92	62.00	83.00	12.34
Motorcyclists killed	72.86	4.34	67.00	79.00	5.95
During daylight	89.57	7.32	80.00	98.00	8.18
Men drivers killed	104.86	4.98	99.00	112.00	4.75
Inside built-up areas	139.00	9.88	127.00	153.00	7.11
Total road fatalities	168.71	12.11	150.00	184.00	7.18

RESULTS AND DISCUSSION

Descriptive Findings

Annual totals ranged 150–184 (lowest 2020, peak 2021). Highest mean counts: Men drivers (104.9), Inside built-up areas (139.0), During daylight (89.6), Motorcyclists (72.9), During nighttime (72.3), Pedestrians (44.4). Lowest: Children (1.7), Cyclists (2.1).

Cluster Analysis:

- Cluster 1: Low-volume / volatile: Children, cyclists, non-national drivers, women drivers, rain conditions, small but variable counts.
 - Cluster 2: Vulnerable users & behavioural risk: Motorcyclists, pedestrians, single-vehicle crashes, nighttime, sensitive to exposure and behaviour.
 - Cluster 3: High-volume / systemic risk: Men drivers, inside built-up areas, daylight, structurally dominant categories.
- Pre-/Post-COVID Comparison (statistically significant, $p < 0.05$):
- ✓ Single-vehicle crashes increased post-COVID: +19%, $p = 0.03$
 - ✓ Children killed decreased post-COVID: -4.8%, $p = 0.01$
 - ⚠ Non-national riders: descriptive +74% but $p = 0.99$ (non-significant, small N, high variability)

Table 4. Linear regression results by fatality category, Attica (2016–2022).

Category	Pre_COVID Mean	Post_COVID Mean	Change	% Change	p-value (t-test)
Children killed (0-14)	1.75	1.67	-0.08	-4.76	0.01
Cyclists killed	1.75	2.67	0.92	52.38	0.43
During daylight	93.50	84.33	-9.17	-9.80	0.09
During nighttime	72.25	72.33	0.08	0.12	0.49
Inside built-up areas	139.75	138.00	-1.75	-1.25	0.34
Killed in single-vehicle crashes	50.75	60.67	9.92	19.54	0.03
Men drivers killed	103.75	106.33	2.58	2.49	0.52
Moped riders killed	3.50	2.33	-1.17	-33.33	0.96
Motorcyclists killed	72.75	73.00	0.25	0.34	0.52
Non-national drivers killed	10.25	14.00	3.75	36.59	0.95
Non-national riders killed	6.50	11.33	4.83	74.36	0.99
Older drivers killed (65+)	16.50	19.67	3.17	19.19	0.86
On motorways	15.25	14.00	-1.25	-8.20	0.54
Outside built-up areas	32.25	26.33	-5.92	-18.35	0.91
Pedestrians killed	48.25	39.33	-8.92	-18.48	0.75
Total road fatalities	172.00	164.33	-7.67	-4.46	0.13
When raining	6.50	6.67	0.17	2.56	0.39
Women drivers killed	4.50	5.67	1.17	25.93	0.36
Young drivers killed (18-24)	13.50	16.33	2.83	20.99	0.58

CONCLUSIONS

- Motorcyclists, pedestrians, and urban road users consistently account for the highest fatality counts in Attica across 2016–2022
- Single-vehicle crashes increased significantly post-COVID ($p = 0.03$, +19%); children killed decreased significantly ($p = 0.01$), consistent with post-pandemic behavioural shifts in travel patterns
- Non-national riders warrant continued monitoring despite non-significance (descriptive +74%) Trend regression reveals weakly linear patterns, fatality dynamics are complex and multi-factorial
- Findings are consistent with Safe System principles: prioritise vulnerable road users, manage behavioural risk, and improve exposure management in urban settings
- Future work should incorporate spatial exposure data (traffic volume, population density, land use) to build targeted regional action plans under Greece's 2030 Road Safety Strategy