

Spatial and Temporal Pattern Analysis of Road Traffic Crash: A Case of Addis Ababa, Ethiopia

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Background

Conventional road safety research often relies on the urban-rural dichotomy, a binary classification that fails to capture the nuanced transitions in traffic exposure, road infrastructure, and road users' behavior that vary across city centers and their peripheries. In rapidly urbanizing African cities, contexts like Addis Ababa, crash characteristics shift significantly across this continuum due to variations in congestion levels, vehicle operating speeds, and land-use characteristics. The availability of crash location coordinate data and methodological advancements in spatial analysis present ample opportunities to explore the underlying spatial processes that influence crash outcomes. Understanding the spatial and temporal pattern of crashes is critical for designing spatially targeted interventions, optimizing enforcement strategies, and prioritizing mitigation measures where the risk of fatal and serious injuries is highest.

Aim

This study aims to investigate how crash severity and collision types vary across the urban center-to-periphery continuum, taking Addis Ababa as a case, and utilizing equally spaced grids to identify distinct spatial and temporal patterns and risk factors.

Method

The study analyzed three years (2015-2017) of georeferenced police-reported road traffic crash data from Addis Ababa city. Crashes were spatially aggregated into equally spaced 400 m grid zones, and the distances of each grid center were measured from the spatial mean center of all crash locations. Crash variables, including injury severity, collision type, time of day, day of week, land use, vehicle age, and driver experience, were used in the analysis. Descriptive statistics were used to explore spatial and temporal distributions, and Multinomial logistic regression models were then estimated to quantify the effects of spatial distance, temporal factors, land use, collision type, and vehicle and driver characteristics on crash severity outcomes.

Results

Clear and systematic spatial gradients in crash severity were observed across the urban center-periphery. Inner-city zones were characterized by a higher proportion of minor injury crashes, possibly due to lower operating speeds and higher congestion levels. In contrast, the intermediate and outer zones exhibited substantially higher shares of fatal and serious injury crashes, consistent with higher speeds and higher road functional classes. Temporal patterns also varied spatially: fatal crashes peaked during late evening and nighttime hours in inner and

intermediate zones, whereas in outer zones they occurred more frequently during daytime periods. Minor injury crashes in inner zones were concentrated during daytime hours.

Five dominant collision types, namely, rear-end, at-angle, sideswipe, vehicle–pedestrian, and head-on collisions, accounted for approximately 95% of all crashes. Vehicle–pedestrian collisions posed the highest risk of fatal outcomes across all locations. Regression results indicated that crashes occurring in the morning and afternoon were significantly less likely to result in fatal injuries compared with nighttime crashes, while weekends were associated with elevated risks of fatal and serious injuries. The probability of severe injury increased with distance from the city center. Land-use showed that factory, rural, recreational, and office areas were associated with higher fatal crash risks, whereas commercial areas were more strongly linked to minor injuries. Certain collision types, including overturning, collisions with static objects, vehicle–pedestrian collisions, and collisions with parked vehicles, were significantly more likely to result in severe outcomes. Finally, inexperienced drivers and older vehicles were also associated with increased injury severity.

Conclusions

- The likelihood of crash severity increases significantly as one moves from the city center toward the periphery.
- Nighttime and weekend periods represent critical high-risk temporal windows, particularly for severe crashes.
- Vehicle–pedestrian collisions are the most dangerous collision type across all spatial zones.
- Spatially targeted interventions are very important; for instance, inner cities require pedestrian-focused safety measures, while outer zones require stricter speed management and nighttime enforcement.
- The spatial zoning approach provides a more granular understanding of crash dynamics than the traditional urban-rural dichotomy.