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An integrated survey–GIS and random-parameters ordered probit approach to modeling road accident severity in Amman

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Abstract

Traffic crashes constitute a major global safety and public health concern, particularly in rapidly developing urban contexts. This study aims to identify and quantify the key determinants of road accident severity in Amman, Jordan, with a focus on both observable and unobserved contributing factors. The study adopts an integrated analytical framework combining crash data analysis, Geographic Information Systems (GIS)-based hotspot identification, field observations, and stakeholder surveys. A Random Parameters Ordered Probit (RPOP) model is employed to account for unobserved heterogeneity in the relationship between crash severity and explanatory variables. The analysis incorporates temporal factors (season, day of the week, crash time), crash characteristics (type of collision), driver attributes (age, gender, behavior), roadway and environmental conditions (lighting, weather, speed limits), and vehicle type. Hazardous locations were identified using Traffic Department records and validated through spatial hotspot mapping and on-site investigations. Additionally, structured questionnaires were administered to drivers and traffic police to capture behavioral patterns, knowledge of traffic regulations, and professional insights into crash causation. The results reveal that driver non-compliance, adverse weather conditions, older driver age groups, pedestrian involvement, and poor vehicle conditions significantly increase the likelihood of higher crash severity levels. The findings also demonstrate the presence of substantial unobserved heterogeneity across observations, justifying the use of the RPOP modeling approach. Crash severity in Amman is influenced by a complex interplay of human, environmental, vehicular, and infrastructural factors. Addressing these elements requires a multidimensional and data-driven approach that accounts for both measurable variables and latent behavioral differences. The study recommends a combination of short-term and long-term interventions, including targeted law enforcement, public awareness campaigns, roadway design improvements, stricter vehicle inspection systems, and the implementation of intelligent transportation systems (ITS). These measures can support policymakers and practitioners in developing effective strategies to enhance road safety and reduce crash severity in urban environments.

Keywords: Accident severity, Driver behavior; Jordan, GIS hotspot analysis, Random Parameters Ordered Probit (RPOP), Road crash modeling, Traffic safety.

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1. Introduction

Road traffic accidents are a major global safety and public health concern, with the World Health Organization (WHO) reporting approximately 1.24 million fatalities and up to 50 million injuries annually. Over 90% of traffic-related deaths occur in developing countries, with pedestrians accounting for nearly half of the victims. Projections indicated that by 2020, road traffic accidents would become one of the leading causes of death worldwide. Jordan reflects this alarming trend, as rapid population growth and increased motorization have been accompanied by a surge in crashes. By 2025, Jordan’s population reached 11.5 million, and police reports documented 144,521 crashes in that year alone. These resulted in 750 fatalities, 1,841 serious injuries, over 15,000 minor injuries, and an estimated economic loss exceeding 323 million Jordanian dinars. Aggressive driver behavior, non-compliance with traffic priorities, and disregard for rules are key contributors to the rising burden of accidents in Amman.

1.1. Objectives

The study seeks to address the growing road safety challenge by:

1. Identifying key factors contributing to road traffic accidents in Amman.
2. Estimating the proportion of drivers knowledgeable about traffic laws.
3. Analyzing reasons behind drivers’ violations of traffic rules.
4. Investigating the main determinants of injury severity using appropriate statistical models.
5. Applying Geographic Information System (GIS) tools to detect accident hotspots.
6. Proposing evidence-based solutions and recommendations to reduce accident frequency and severity while improving driver behavior.

1.2. Methodology

The research methodology is structured in eleven stages, beginning with a comprehensive literature review and progressing through accident data collection from Amman’s road network. The Random Parameters Ordered Probit (RPOP) model was applied to assess severity determinants, while GIS analysis was employed to identify accident accumulation zones. Engineering assessments were combined with pilot surveys targeting both drivers and traffic police. The surveys captured vehicle and driver characteristics, behavioral aspects, knowledge of traffic laws, and perceptions of accident causes. Data analysis of these surveys and crash records enabled the identification of behavioral, environmental, and infrastructural risk factors. Finally, results were synthesized into actionable short- and long-term recommendations.

1.3. Literature Review

1.3.1. Determinants of Accident Severity

The determinants of road traffic accident severity have been widely examined and are generally categorized into four main groups: vehicle-related, environmental, driver-specific, and roadway geometric factors. Vehicle characteristics, including type, age, and model year, significantly influence crash outcomes. For example, motorcycles and older vehicles are often associated with higher injury severity due to limited occupant protection [1, 2].

Environmental conditions such as weather, pavement condition, and visibility also play a critical role. Adverse conditions, including wet or icy roads, tend to increase crash likelihood; however, some studies suggest that drivers may adopt more cautious behavior under such conditions, potentially reducing severity [3, 4].

Driver-related factors remain among the most extensively studied determinants. Variables such as age, gender, alcohol consumption, fatigue, and seatbelt use have been consistently linked to crash severity. Older drivers and impaired individuals are generally associated with higher injury severity and fatality risk [5, 6].

Roadway geometric characteristics, including speed limits, number of lanes, intersection design, and roadside features, further influence crash outcomes. Prior studies emphasize that infrastructure design and traffic control measures are critical in mitigating crash severity [7, 8].

1.3.2. Modeling Approaches in Accident Severity Analysis

A variety of statistical and machine learning models have been employed to analyze and predict accident severity. Early studies primarily utilized ordered response models, such as ordered logit (OL) and ordered probit (OP), which account for the ordinal nature of severity outcomes (e.g., property damage, injury, fatality) [5, 6]. However, these models assume parameter homogeneity across observations, which may lead to biased estimates in the presence of unobserved heterogeneity.

Alternative discrete choice models, including the multinomial logit (MNL), relax the ordinal assumption but fail to exploit the inherent ordering of severity levels. The nested logit (NL) model addresses correlation across outcome categories but introduces additional structural complexity [8].

To overcome these limitations, advanced econometric models such as heteroskedastic ordered logit (HOL) and mixed logit (MXL) have been developed. These models allow for random parameters and varying error variances, thereby capturing unobserved heterogeneity more effectively [9, 10]. Bayesian approaches have also been introduced, particularly for small or complex datasets, demonstrating improved estimation performance [11].

In parallel, machine learning techniques, including classification and regression trees (CART), random forests, and boosting methods, have gained popularity due to their strong predictive capabilities [12-14]. Despite their ability to model nonlinear relationships and interactions, these methods often lack interpretability, which limits their applicability for policy-oriented analysis compared to traditional econometric models.

1.3.3. Empirical Findings from Previous Studies

Empirical evidence consistently highlights the multifaceted nature of crash severity determinants. Using a nested logit framework, prior research found that wet pavement and male drivers significantly increased severity in single-vehicle crashes, while snow and ice conditions were associated with reduced severity due to more cautious driving behavior [8].

Similarly, studies employing ordered probit and related models have shown that older drivers face a higher probability of severe injury, with fatality risks increasing substantially for drivers above 80 years of age [5]. Other research has identified alcohol consumption, pedestrian involvement, and advanced pedestrian age as key contributors to higher severity levels [6].

Infrastructure and environmental factors also play a significant role. For instance, wrong-way driving has been associated with increased crash severity, whereas intersection-related crashes tend to be less severe [7]. Comparative analyses of modeling approaches indicate that ordered probit models effectively capture ordinal outcomes, while nested logit models may provide improved statistical fit at the expense of model simplicity [5, 8].

Studies focusing on vulnerable road users consistently report higher severity levels. Pedestrian-related crashes, particularly involving elderly or intoxicated individuals, are more likely to result in severe injuries, especially under poor lighting and adverse weather conditions [1, 3]. Similarly, motorcycle involvement, high-speed environments, and frontal collisions have been linked to increased severity, whereas seatbelt use and adequate lighting conditions reduce injury outcomes [2, 9].

Recent research incorporating mixed logit and Bayesian frameworks has demonstrated the importance of accounting for heterogeneity. For example, mixed logit models reveal that the effects of traffic volume and weather conditions vary across observations [9]. Bayesian ordered probit models have shown improved performance in handling complex datasets and limited samples [11]. Machine learning approaches, including neural networks, have also been applied, often achieving higher predictive accuracy but offering limited explanatory insight [13, 14].

1.3.4. Limitations of Previous Studies

Despite extensive research, several limitations persist in the literature. First, accident severity is inherently ordinal and discrete; however, some modeling approaches fail to adequately capture correlations between adjacent severity levels, potentially leading to biased estimates. Second, many studies rely on fixed-parameter models, which do not account for unobserved heterogeneity across drivers, vehicles, and roadway environments.

Third, data-related challenges remain significant. Issues such as omitted variable bias, measurement errors, and limited availability of detailed crash data reduce the robustness and generalizability of findings. As emphasized in [8] the omission of correlated variables may result in inconsistent parameter estimates, thereby affecting model reliability.

1.3.5. Research Gap and Contribution

To address the identified limitations, this study employs a Random Parameters Ordered Probit (RPOP) model, which accounts for unobserved heterogeneity while preserving the ordinal structure of severity outcomes. To the best of the authors' knowledge, this represents one of the first applications of the RPOP framework in the context of Jordan.

By integrating crash data, geographic information system (GIS)-based hotspot analysis, and survey data, this study provides a comprehensive assessment of accident severity determinants in Amman. The findings contribute both methodologically and empirically, offering actionable insights for policymakers and supporting the development of targeted road safety interventions in rapidly urbanizing regions.

2. Methodology

This chapter outlines the methodological framework employed to achieve the research objectives. The process involved five major components: (i) selection of case study sites, (ii) determination of sample size, (iii) spatial mapping of accident locations using ArcGIS, (iv) design and administration of driver and police questionnaires, and (v) statistical analysis using the Random Parameters Ordered Probit model.

2.1. Selection of Study Sites

Although traffic accidents can occur anywhere and at any time, certain locations consistently exhibit higher crash frequencies and severities, thus classifying them as hazardous. In Jordan, such sites are commonly referred to as *black points*—road sections or intersections characterized by disproportionately high accident occurrence or injury risk.

According to the Jordan Traffic Institute [8] approximately 403 hazardous locations were identified across the country, with 303 situated in Amman alone. Amman was chosen as the study area for several reasons. First, it consistently records the highest number of traffic crashes in Jordan, accounting for 39.4% of all injury-related crashes nationwide. It also contributes 32.1% of national road fatalities and 43.3% of pedestrian deaths, alongside the highest rates of minor and major injuries (39.7% and 32.9%, respectively). Second, Amman serves as Jordan's demographic and economic hub, attracting residents, migrants, and tourists due to its concentration of commercial centers and leading universities (e.g., University of Jordan, Princess Sumaya University for Technology, Petra University). Additionally, regional instability has contributed to an influx of immigrants, further exacerbating urban congestion and traffic exposure. The identification of black points relied on the Weighted Injury Accident (WIA) index developed by the Ministry of Public Works and Housing:

$$W + I + A \geq 10 \quad (1)$$

where W represents the number of fatalities (multiplied by 3), I the number of injuries, and A the number of property-damage-only accidents (multiplied by 1/3).

Based on this criterion, seven critical sites were selected for in-depth analysis, four of which form the focus corridors in this study: Mecca Street (Al-Shaeb Roundabout to Al-Kilo Roundabout), Al-Madenah Al-Monawara Street (Al-Kilo Roundabout to Al-Shaeb Roundabout), Abdullah Ghosheh Street, and Zahran Street (Seventh to Sixth Roundabout). Figure 1 illustrates the distribution of hazardous locations across Jordan, where red points indicate fatal crashes, orange points denote injury crashes, and green points mark property damage crashes.

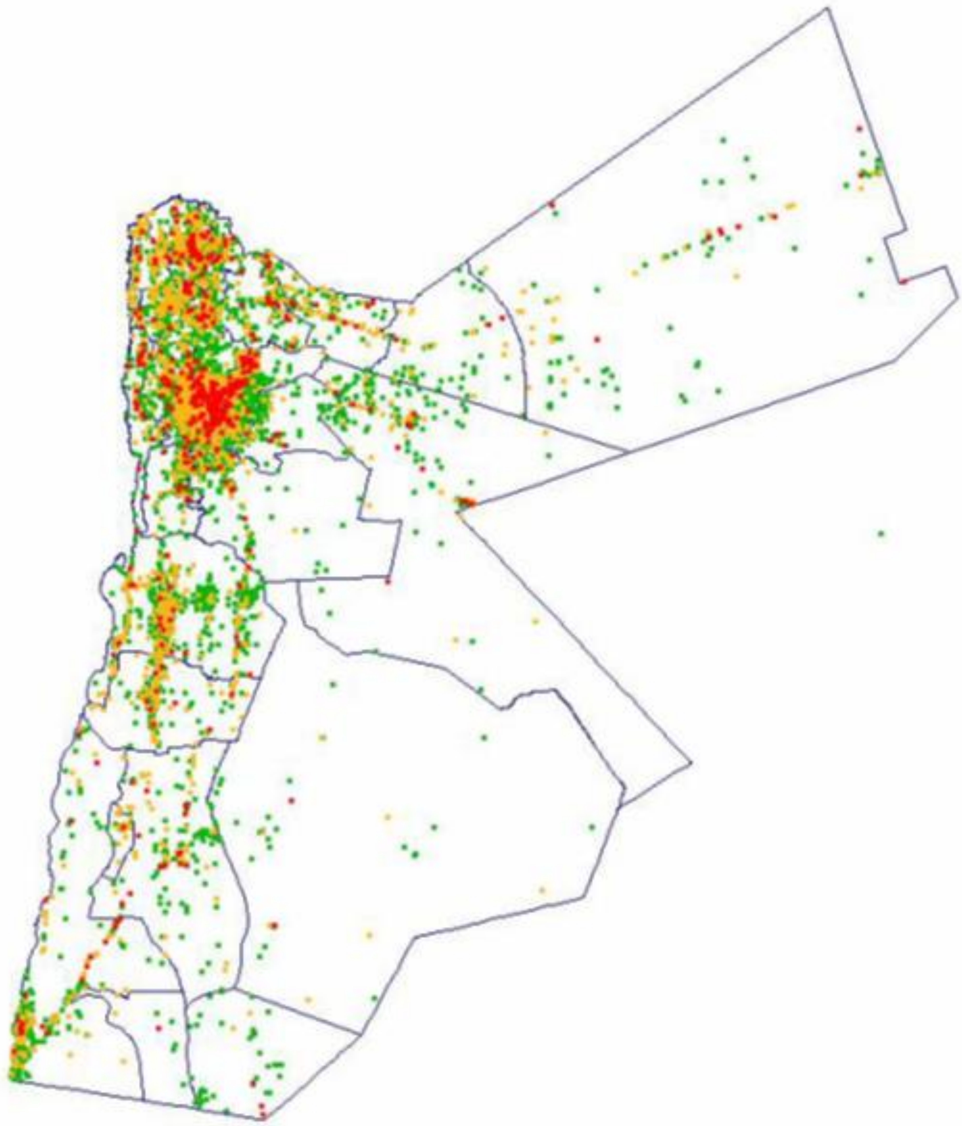

Figure 1.
Data of traffic accidents projected on Jordan map for year 2025.
Source: Jordan Traffic Institute [8]

2.2. Sample Size Determination

The sample size for accident records and survey participants was calculated using Equation 2:

$$n = \frac{(Z^2)\sigma^2}{(E^2)} \quad (2)$$

where Z represents the confidence interval, σ^2 the sample variance, and E the margin of error. A 95% confidence level and a 5% margin of error were adopted. Based on the 144,521 crashes reported in Jordan Traffic Institute [8] the minimum required sample was 384 accidents. Restricting the focus to Amman, which recorded 4,272 crashes in 2024, yielded a required sample of 353 accidents. To ensure reliability, data from 427 crashes were collected. Similarly, for the surveys, 423 driver responses were obtained against a required minimum of 384, and 323 police responses were collected compared to a calculated requirement of 317. These sample sizes exceeded the thresholds, ensuring statistically valid representation.

2.3. Accident Location Analysis Using GIS

In Jordan, police involvement in a traffic crash results in the completion of an Accident Participation report and a Statistical Bulletin of Road Accidents (SBRA), which document crash circumstances and locations. For this study, accident records for Amman in 2025 were obtained from the Urban Police Department. The data enabled spatial mapping of crash concentration zones using Geographic Information System (GIS) tools. Analysis revealed clustering along major corridors, particularly Mecca Street, Abdullah Ghosheh Street, Al-Madenah Al-Monawara Street, and the Zahran corridor linking the Sixth and Seventh Roundabouts. These streets are interconnected, forming a critical network of high-risk sites. Their spatial connectivity likely contributes to their designation as hazardous corridors. To further explore causal factors, targeted questionnaires were administered to frequent road users and traffic police officers, complementing the GIS-based hotspot analysis with behavioral and experiential insights.

2.4. Drivers' Questionnaire Structure

The driver questionnaire was designed to capture four dimensions: (i) socio-demographic characteristics (e.g., license status, gender, age, education, profession, income, vehicle type, and driving experience); (ii) knowledge of traffic rules, assessed through multiple-choice and scenario-based questions; (iii) self-reported driving behavior, including adherence to speed limits, intersection practices, and accident history; and (iv) perceptions of systemic and environmental contributors to crashes, such as traffic control, road maintenance, enforcement, and driver behavior. This structured approach provided insights into both objective knowledge and subjective attitudes toward road safety.

2.5. Traffic Police Questionnaire Structure

The second instrument targeted traffic police officers, who represent a key stakeholder group with firsthand experience in accident investigation and enforcement. The questionnaire examined officers' perspectives on drivers' behavior, enforcement practices, environmental conditions, and vehicle-related factors influencing accident occurrence and severity. Police were asked to evaluate the relative importance of risk factors such as speeding, non-compliance with traffic rules, weather, congestion, driver age, and vehicle condition. The responses provided a professional counterbalance to driver self-reports, enabling triangulation of results.

2.6. Data Collection Procedures

Driver questionnaires were distributed between February and March 2024 across multiple community settings, including universities, schools, ministries, malls, and commercial centers, ensuring a representative sample across age, gender, education, and income groups. Police surveys were distributed to officers stationed in high-risk corridors, as well as those working in Al-Bayader and Tla'a Al-Ali traffic centers. In total, 423 valid driver responses and 323 police responses were collected, exceeding the minimum sample size requirements.

2.7. Statistical Modeling Approach

To analyze injury severity outcomes, the study employed an Ordered Probit (OP) model, which assumes an underlying continuous latent variable representing crash severity. Observed severity levels (slight, severe, fatal) correspond to intervals of this latent variable, with thresholds estimated along with model coefficients. Probabilities of each severity level are derived using the cumulative normal distribution.

2.8. Random Parameters Ordered Probit Model

While the OP model accounts for the ordinal nature of severity outcomes, it assumes fixed coefficients across all observations, limiting its ability to capture unobserved heterogeneity. To address this, the Random Parameters Ordered Probit (RPOP) model was applied. This extension allows parameter estimates to vary randomly across individuals, reflecting differences in driver behavior, vehicle conditions, and crash environments. By incorporating random components into coefficient estimations, the RPOP model improves explanatory power and reduces bias associated with fixed-parameter models. This methodology enables a more realistic representation of the diverse factors contributing to accident severity in Amman.

The main reason of using ordered probit model in this study is the ability of this model to account for the ordered-nature injury severity (i.e. 1 for slight injuries, 2 for severe injury, and 3 for fatality). Ordered probit model assume the existence of a continuous latent variable (z), and random error associated with this continuous variable that is assumed to follow a normal distribution [15]. The normality assumption made by ordered probit models allows conditional heteroskedasticity to be captured more easily than other models. Also, normality assumption enables altering the probabilities of observing each severity outcome by shifting the thresholds [16]. The function for the latent variable can be defined as a linear function of each accident as follows [15].

$$z = \beta X_{acc} + \boldsymbol{\varepsilon_{acc}} \quad (3)$$

where z is the latent injury risk variable for each accident, Xacc is a vector of the independent variables considered, β is the vector of estimable coefficients, and εacc is a random error term assumed to follow the standard normal distribution across individuals. The observed values of injury yacc can be given as a function of the latent variable z as shown in Equation 2 [15].

$$y_{acc} = \begin{Bmatrix} 0 & if - \infty < z \leq \mu_1 & (slight\ injury) \\ 1 & if \quad \mu_1 < z \leq \mu_2 & (sever\ injury) \\ 2 & if \quad \mu_2 < z < +\infty & (fatal\ injury) \end{Bmatrix} \quad (4)$$

The symbols μ1, μ2 are the thresholds which are constant, and they are estimated by the model along with β. Then, the probability of each injury level (0, 1, 2) is given by Greene [15].

$$\begin{gathered} P(y_{acc} = 0|X_{acc}) = \varphi(\mu_1 - X_{acc}\beta) \\ P(y_{acc} = 1|X_{acc}) = \varphi(\mu_2 - X_{acc}\beta) - \varphi(\mu_1 - X_{acc}\beta) \\ P(y_{acc} = 2|X_{acc}) = 1 - \varphi(\mu_2 - X_{acc}\beta) \end{gathered} \quad (5)$$

Where $\varphi(\mu)$ is the cumulative normal distribution, given by equation 4.

$$\varphi(\mu) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\mu} e^{-0.5\alpha^2}\, \partial\alpha \quad (6)$$

It should be noted that in Equation 3, the threshold (μ_1) can be set equal to zero without loss of generality [16]. However, some assumptions of the standard probit model pose limitations to its application, one of these assumptions is that both independent variables coefficients and the thresholds are fixed across drivers. Therefore, possible heterogeneity among observations is not properly addressed by standard ordered probit model. This research uses random parameters ordered probit model to address this drawback and consider everyone with specific characteristics that may influence the severity outcomes, thus allowing the influences of variables affecting accident injury-severity proportions to vary across observations. This is achieved by adding a randomly distributed error term (ɷ) as shown by Equation Greene [15].

$$\beta_{acc} = \beta + \omega_{acc} \quad (7)$$

Then Equation 3 can be rewritten as Greene [15].

$$y_{acc} = \beta X_{acc} + \epsilon'_{acc} \quad (8)$$

where ϵ'_{acc} is the new error term Greene [15].

$$\epsilon'_{acc} = \boldsymbol{X_{acc}\omega_{acc}} + \boldsymbol{\varepsilon_{acc}} \quad (9)$$

3. Results and Discussion

3.1. Statistical Model Performance

Accident severity was modeled using both fixed parameters Ordered Probit (OP) and Random Parameters Ordered Probit (RPOP) specifications. Simulation-based maximum likelihood estimation with Halton draws was applied to estimate model parameters. The fixed-parameter OP identified only a limited set of significant predictors (weather, time of crash, and vehicle type), suggesting restricted explanatory power. By contrast, the RPOP model accounted for unobserved heterogeneity, yielding more robust results and identifying weather, accident type, and driver age as key determinants of severity.

Consistent with prior research, adverse weather conditions (rain or snow) significantly increased the probability of severe and fatal crashes compared to clear weather. Accidents involving pedestrians showed the highest likelihood of fatal outcomes, while vehicle deterioration-related crashes were less severe. Driver age was also significant, with older drivers (>60 years) facing disproportionately higher fatality risks, whereas younger drivers (18–32 years) exhibited lower severity probabilities. The marginal effects further confirmed these associations: for example, each additional year of driver age increased the probability of a fatal crash by 0.3%. Model comparison using the Akaike Information Criterion (AIC) and likelihood ratio tests indicated that the RPOP substantially outperformed the fixed OP model. The RPOP achieved a lower AIC value (568.8 vs. 772.8) and a significant likelihood ratio statistic, confirming the importance of accounting for heterogeneity in crash severity modeling.

3.2. GIS-Based Hotspot Analysis

Spatial mapping of 427 crashes in Amman using ArcGIS highlighted intersections as the most accident-prone locations. Hotspot clustering was particularly evident along Mecca Street, Abdullah Ghosheh Street, Al-Madenah Al-Monawara Street, and Zahran Street (between the Sixth and Seventh Roundabouts). Daily field visits revealed recurrent congestion during peak hours, with queuing, bottlenecks, and aggressive driving behaviors contributing to elevated crash risks. Observed issues included insufficient lanes, on-street parking reducing road capacity, frequent merging/diverging conflicts, and disregard of pedestrian facilities. These findings reinforce the role of both infrastructure design and driver behavior in shaping accident patterns.

3.3. Driver Survey Insights

Analysis of 423 driver responses provided further context. Most respondents owned private cars (61%), followed by service vehicles (15%) and buses (14%). Low-income groups (<500 JD monthly) comprised 57% of participants, highlighting affordability pressures that encourage private vehicle ownership despite economic constraints. Young drivers (18–32 years) accounted for 63% of respondents, aligning with their overrepresentation in crash statistics. Educational attainment was generally high, with 64% holding university degrees, but 35% still demonstrated limited knowledge of traffic rules.

Behavioral analysis revealed risk-taking tendencies: over half (53%) admitted to exceeding speed limits when late, and nearly 28% did not reduce speed at intersections even when clear. Many drivers reported involvement in multiple accidents within the study corridors, underscoring their classification as blackspots. Respondents also indicated insufficient lane capacity and poor road maintenance as contributors to congestion and unsafe conditions.

Regarding accident causation, over 90% of drivers cited non-compliance with traffic laws and congestion-induced speeding as leading factors. Additional high-impact contributors included weak driving experience, over speeding, poor vehicle condition, and adverse weather. When rating severity escalators, over speeding (92%), poor vehicle condition (82%), aging drivers (81%), and bad weather (70%) were considered the most critical.

3.4. Synthesis of Findings

The combined evidence from statistical models, GIS mapping, and survey results emphasizes the multifactorial nature of road accident severity in Amman. Structural issues such as congestion and insufficient road capacity interact with driver behavior (non-compliance, speeding, fatigue) and demographic factors (youth and elderly drivers) to elevate risk. Importantly, the RPOP model demonstrated the necessity of accounting for heterogeneity, particularly in age-related and pedestrian-involved crashes. These insights provide a strong empirical basis for targeted interventions in enforcement, infrastructure improvement, and public awareness.

On other hand, the perceptions of traffic police officers provide a critical complement to driver survey findings, as officers observe road user behavior and accident patterns daily. Responses highlighted widespread agreement on the dominant factors contributing to crash occurrence. Nearly all officers (97.2%) identified non-compliance with traffic rules at signals, intersections, and along roadways as a primary cause of accidents, closely followed by lack of respect for traffic laws (95.8%). Other major contributors included weak driver experience (93.7%), insufficient knowledge of traffic laws (92.8%), and speeding (91.3%). Additional factors cited included poor vehicle condition (81.2%), adverse weather conditions (71.4%), reckless driving by young drivers (69.3%), and older driver age (68.3%). Only half of respondents (50.2%) emphasized the absence of strict enforcement as a key contributor, though this still signals an important enforcement gap. Police officers also assessed the factors most likely to exacerbate accident severity. As illustrated in Figure 4.51, vehicle type (e.g., trucks, buses, cars) was considered the most critical determinant (82.6%), followed by lack of knowledge of traffic laws (81.3%), adverse weather conditions (78.4%), and over speeding (74.8%). These insights are consistent with the driver questionnaire results, reinforcing the conclusion that behavioral non-compliance, inadequate driving skills, poor vehicle conditions, and environmental factors collectively drive both the frequency and severity of crashes in Amman.

4. Conclusion and Recommendations

This study investigated the determinants of accident severity on high-risk corridors in Amman, combining statistical modeling with spatial and survey-based analyses. Accident data from the Traffic Institute were evaluated using fixed- and random-parameters ordered probit models. Comparative results demonstrated that the random-parameters specification outperformed the fixed model, as confirmed by log-likelihood and Akaike Information Criterion (AIC) statistics. The findings indicated that weather conditions exert a fixed effect, while driver age and accident type vary across individuals. Specifically, accidents under snowy or rainy weather were more likely to be severe; drivers aged over sixty exhibited the highest likelihood of involvement in severe crashes (84% of observations); and pedestrian-involved collisions carried the greatest probability of severe outcomes.

Complementary surveys of drivers and traffic police revealed convergent perceptions regarding key risk factors. Both groups emphasized non-compliance with traffic laws, weak driver experience, and speeding as primary contributors to accident occurrence and severity. Importantly, police officers highlighted poor vehicle condition and insufficient enforcement as aggravating factors, while drivers stressed traffic congestion and inadequate infrastructure. These perspectives underscore the multidimensional nature of road safety challenges in Jordan.

Based on the evidence, several recommendations are proposed:

1. Driver knowledge and awareness: Expand education on traffic laws through social media, public campaigns, and integration into school and university curricula. This long-term intervention would ensure that younger generations internalize safe driving practices.
2. Traffic police capacity building: Conduct regular training and refresher sessions to improve enforcement strategies and traffic flow management.
3. Vehicle ownership and public transport: Control rising private vehicle ownership by strengthening customs policies, incentivizing cycling infrastructure, and improving public transportation. Measures include expanding bus fleets, establishing fixed schedules, and enhancing passenger comfort, thereby reducing reliance on private cars.
4. Parking and road capacity: Provide off-street parking using vacant land or multi-story garages and expand roadway capacity where feasible. Although land-use constraints limit large-scale re-zoning, targeted interventions can alleviate localized bottlenecks.
5. Travel time reliability studies: Publish real-time travel time forecasts online and via mobile platforms, enabling users to adjust departure times and reducing peak-hour congestion.
6. Infrastructure development: While additional traffic signals and roundabouts have limited potential due to space constraints, long-term investment in a subway system could fundamentally reduce road demand, linking critical urban corridors.
7. Vehicle maintenance and renewal: Promote periodic vehicle inspections and incentivize replacement of vehicles older than five years, reinforcing existing government initiatives.
8. Traffic signs and road maintenance: Increase driver awareness of traffic signage and improve municipal road maintenance, including pothole repair and pavement markings, to directly enhance safety and reduce accident risk.

In summary, the integration of advanced statistical modeling, GIS analysis, and stakeholder perspectives provides a robust evidence base for improving traffic safety in Amman. Addressing behavioral, infrastructural, and institutional dimensions in parallel is essential to reducing both the frequency and severity of accidents in high-risk urban corridors.

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