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Analysis of important accident cases that led to deaths in Isfahan province suburb

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ABSTRACT

This study analyzes fatal traffic accidents on intercity roads in Isfahan province, Iran. Given the high rate of fatalities from traffic accidents in Iran, this study aims to identify the main contributing factors to fatal accidents and provide solutions to increase road safety. Using 26 official accident sketches obtained from Isfahan Traffic Police, this study evaluates accident types, contributing factors (human, vehicle, infrastructure), and road categories using a descriptive-analytical method. The results show that a significant portion of fatalities occurred on the Kashan-Isfahan freeway and Isfahan-Shiraz highway, and vehicle rollovers account for almost half of the recorded fatal accidents. In addition, rural and secondary roads account for more than one-third of the cases. Based on the findings, infrastructure improvements (e.g., flexible barriers, better lighting, clearer signs), advanced driver training, and integration of intelligent monitoring systems are recommended. While this study points to machine learning as a promising future direction, no predictive models have been applied at the current stage. These insights offer practical implications for transportation safety planning on high-risk routes in Isfahan province.

1. Introduction

Road traffic accidents (RTAs) are among the leading causes of mortality and injury worldwide, accounting for over 1.3 million deaths and approximately 50 million injuries each year (World Health Organization, 2019). The burden of RTAs is particularly severe in low- and middle-income countries, where over 90% of these deaths occur. In Iran, traffic accidents consistently rank among the top causes of unnatural death and are estimated to impose a financial burden exceeding 7–10% of the national GDP annually (Yousefifard et al., 2021). Beyond the economic impact, road crashes contribute to long-term social consequences, including disability, emotional trauma, and generational disruption.

The multifactorial nature of traffic accidents, ranging from driver behavior and vehicle conditions to road design and environmental influences, requires multidisciplinary prevention strategies. Accordingly, this study focuses on the analysis of fatal accidents on intercity roads in Isfahan Province, aiming to identify key patterns, highlight infrastructural shortcomings, and propose actionable recommendations to improve road safety outcomes in the region.

In recent years, Iran has witnessed alarmingly high rates of road traffic accidents, with over 25,000

fatalities and 300,000 injuries reported annually (Yousefifard et al., 2021). Isfahan Province, due to its geographic centrality and heavy intercity transit volume, ranks among the most accident-prone regions in the country. Previous studies have highlighted the disproportionate burden of accidents on intercity highways, where infrastructural weaknesses and human factors intersect to heighten risk (Mansouri & Kargar, 2014; Nasr Isfahani et al., 2024). Nowadays intelligent and modern vehicles, systems, and applications have been introduced and developed for transportations (Barenji & Nejad, 2022; Golabi & Nejad 2022). While developed nations such as Sweden, Japan, and the Netherlands have successfully implemented intelligent transportation systems, ranging from automatic braking to obstacle detection, such technologies are still underutilized in Iran (Ghadiri Nejad & Banar, 2018). The present study addresses this gap by focusing on fatal accidents in Isfahan's intercity roads, aiming to extract patterns and offer practical solutions grounded in empirical evidence.

Given the magnitude of the road safety crisis in Iran and the specific vulnerabilities of intercity transit corridors in Isfahan Province, this study aims to conduct an in-depth analysis of fatal traffic accidents based on official accident sketches collected from local authorities. By examining the underlying causes, including driver behavior, infrastructural weaknesses, and environmental conditions, the research seeks to identify critical risk patterns. Although this study does not implement predictive modeling at this stage, it highlights the potential for future applications of machine learning and intelligent transport systems (ITSs) in accident prevention. Ultimately, the goal is to offer practical recommendations to improve road safety and reduce fatality rates across high-risk routes in the region.

2. Theoretical Framework and Literature Review

2.1. Definition and Scope of Road Accidents

Road traffic accidents (RTAs) are typically defined as incidents occurring on public roads that involve at least one moving vehicle and result in injury, death, or property damage. According to the World Health Organization (2019), RTAs remain a leading cause of death globally, particularly among young adults aged from 15 to 29. These incidents impose a significant burden on public health systems, economies, and societies at large.

In most cases, road accidents are not attributable to a single cause but are rather the outcome of a complex interaction among human factors, like driver behavior or fatigue; environmental conditions, for instance weather and lighting; vehicle-related issues like mechanical failure; and infrastructural deficiencies as poor road design and inadequate signage.

The scope of this problem is particularly severe in low- and middle-income countries, including Iran, where the rate of road traffic fatalities is considerably higher than the global average. Understanding the scope and definitions surrounding RTAs is essential to contextualizing their impact and informing effective interventions.

2.2. Key Contributing Factors

The causes of road traffic accidents are multifactorial and often interrelated. Broadly, these factors can be categorized into four primary domains: human-related, vehicle-related, environmental, and infrastructural.

Human factors include driver behavior such as speeding, distraction, fatigue, violation of traffic laws, and substance use. Studies have shown that human error accounts for a significant proportion of traffic accidents globally (Mansouri & Kargar, 2014). In Iran, research indicates that human factors are involved in nearly 70% of fatal crashes (Nasr Isfahani et al., 2024).

Vehicle-related factors pertain to technical failures, poor maintenance, design limitations, and lack of modern safety features such as electronic stability control or collision avoidance systems. Vehicles operating without regular safety checks are more likely to be involved in accidents, especially under high-speed conditions.

Environmental factors include road visibility, weather conditions (for instance fog, rain, and snow), and lighting. These factors can amplify the risk of accidents when combined with inadequate driving responses or suboptimal infrastructure.

Infrastructural factors relate to road design, quality of signage, surface conditions, presence of barriers, lane width, and the availability of pedestrian crossings or traffic calming measures. Poor infrastructure has been repeatedly linked to higher accident rates, especially in developing countries (Yousefifard et al., 2021).

Understanding the interplay among these factors is essential for the development of comprehensive accident prevention strategies. While some causes may be beyond direct control, like sudden weather changes, many are predictable and preventable through policy, enforcement, education, and technological innovation.

2.3. Analytical Approaches in Road Safety Studies

A wide range of analytical methods has been employed in road safety research to identify risk factors, evaluate intervention outcomes, and predict accident occurrences. These methods can be broadly categorized into five main groups:

Descriptive Statistical Analysis is commonly used to summarize accident data, providing insights into the frequency, severity, and temporal-spatial distribution of crashes. Such approaches often serve as a preliminary step in identifying patterns and high-risk areas (Mansouri et al., 2014).

Regression Models are widely adopted to examine the relationships between independent variables (such as driver age, speed, and road type), and accident severity or likelihood. Linear, logistic, and Poisson regression have been applied to model accident data with both continuous and categorical predictors.

Machine Learning Techniques such as Random Forest, Support Vector Machines (SVM), and Neural Networks are increasingly used for accident prediction. These models can capture nonlinear interactions and are effective when working with large, multidimensional datasets (Wang et al., 2021; Zhao et al., 2019).

Simulation and Dynamic Modeling approaches allow researchers to simulate vehicle interactions, traffic flows, and accident scenarios under various conditions using tools like VISSIM or SUMO. These models provide useful insights for infrastructure planning and policy development.

Geospatial and Risk Mapping Tools use GIS-based platforms to visualize accident hotspots and assess the influence of spatial variables such as road geometry, urban layout, or proximity to schools and intersections (Aghasi et al., 2018; Nasr Isfahani et al., 2024).

The integration of traditional statistical methods with modern data-driven approaches offers a comprehensive understanding of accident dynamics and supports the development of proactive safety strategies.

2.4. Existing Studies and Research Gaps

Several studies have investigated the causes, patterns, and consequences of road traffic accidents across various geographic and socio-economic contexts. In Iran, Mansouri et al. (2014) analyzed accident data from Shiraz and emphasized the role of human factors and infrastructural deficiencies. Their findings highlighted the critical need for better road design, stricter law enforcement, and enhanced public education.

Nasr Esfahani et al. (2024) focused specifically on traffic accident patterns in Isfahan Province, identifying key hotspots and suggesting geospatial tools for monitoring and planning. Their work provided valuable baseline data but did not conduct an in-depth causal analysis or propose specific interventions.

On a broader level, Yousefifard et al. (2021) conducted a national-level systematic review and identified the high incidence of fatalities on rural and intercity roads, particularly emphasizing weaknesses in data systems and the underutilization of modern analytical tools.

Additionally, studies such as Zhao et al. (2019) and Wang et al. (2021) have demonstrated the effectiveness of machine learning algorithms in predicting traffic accidents and risk levels. However, such approaches remain underrepresented in Iranian studies, particularly those targeting provincial-level data.

Despite these efforts, a notable research gap remains in the localized, data-driven analysis of fatal accidents in Isfahan's intercity roads. Few studies have utilized firsthand police records (e.g., accident sketches) as primary data sources, and fewer still have proposed actionable, context-specific safety recommendations. This study seeks to address these limitations by combining descriptive analysis of real-world accident data with targeted proposals for infrastructural and policy improvements.

2.5. Need for Localized Studies in Iran (Focus on Isfahan)

While numerous international studies have explored road traffic accidents through advanced modeling, technological interventions, and policy analysis, such research remains limited in Iran—particularly at the provincial level. National-level reviews, such as that by Yousefifard et al. (2021), provide a broad overview of challenges, but often lack the regional specificity required for actionable interventions.

Isfahan Province, as one of Iran's major transportation hubs, features high intercity traffic density, diverse road types, and significant variation in infrastructural quality. Despite these factors, few data-driven studies

have been conducted in this region using firsthand accident documentation such as police sketches or field reports.

Localized studies are critical for understanding context-specific risk factors and proposing tailored safety solutions. Provincial authorities require evidence-based insights not just for strategic planning but also for targeted infrastructure upgrades and traffic law enforcement. By focusing on fatal accidents documented on Isfahan's intercity roads, this study addresses a notable gap in the literature and offers practical implications for improving road safety in similar regions across Iran.

3. Methods and Material

3.1. Research Design

This study adopts a descriptive-analytical research design, aimed at exploring the patterns and contributing factors of fatal road accidents on intercity roads in Isfahan Province. The research is grounded in empirical data obtained directly from official accident sketches provided by the Isfahan Road Police.

The study follows a field-based, document analysis approach, where real-world cases are used to identify recurring causes, road types, driver characteristics, and infrastructural weaknesses associated with fatal accidents. While the primary method is qualitative in nature, it is supported by structured quantitative summaries derived from categorizing and classifying the recorded data.

Given the exploratory nature of the study, the design does not involve predictive modeling or hypothesis testing, but rather focuses on pattern recognition and contextual analysis, with the aim of providing data-driven recommendations for safety improvement.

3.2. Statistical Population and Sample

The statistical population of this study comprises all fatal traffic accidents that occurred on intercity roads of Isfahan Province between the years 2017 and 2021 (1396–1400 in the Iranian calendar). These include accidents resulting in at least one death and formally recorded by provincial road authorities.

The sample for this research consists of 26 detailed accident sketches obtained from the Isfahan Road Police. These sketches were selected based on availability and completeness of documentation, with a focus on cases involving fatalities and representing diverse road types and causes.

The sampling approach is purposive, aimed at capturing critical, high-impact accident cases rather than achieving statistical generalization. Each sketch served as a case unit for qualitative and descriptive analysis, enabling the extraction of key variables such as road type, accident cause, driver demographics, and infrastructural conditions.

3.3. Data Collection Methods

The data for this study were collected using a combination of documentary and field-based methods. The primary data source comprised 26 official accident sketches obtained from the Isfahan Road Police, which documented the spatial, behavioral, and technical aspects of fatal road traffic incidents. These sketches included detailed information such as collision type, road conditions, driver demographics, and the suspected causes of each accident.

Additionally, a document review was conducted to provide contextual background and comparative insights. This included reviewing previous research articles, national road safety reports, and statistical

data available through the Iranian Road Safety Information System (RAHVAR).

The field aspect involved analyzing accident details as recorded in their original, unedited format. No interventions or surveys were administered, and the researchers played a non-intrusive observational role. The combination of official police data and supporting documentary sources provided a reliable foundation for qualitative analysis and descriptive statistics.

3.4. Data Analysis Techniques

The collected data were analyzed using descriptive and content-based methods, focusing on frequency distributions, categorization, and pattern recognition. Each accident sketch was systematically reviewed to extract key variables, including type of collision, road type, time of occurrence (day/night), driver demographics, cause of accident, and whether infrastructural failure contributed to the event.

The data were then coded into predefined categories and analyzed using Microsoft Excel and basic statistical tools to generate frequency tables, bar charts, and comparative visuals. These visualizations facilitated the identification of common patterns across different accident scenarios, road types, and contributing factors.

No inferential statistical analysis or predictive modeling was employed in this phase, as the study aimed to provide an exploratory understanding based on a relatively small but focused sample. However, the patterns observed may serve as a foundation for future research using advanced analytical techniques such as regression models or machine learning algorithms.

3.5. Limitations and Research Scope

While this study offers valuable insights into the nature and causes of fatal traffic accidents in Isfahan Province, several limitations should be acknowledged. First, the sample size was relatively small (n = 26), constrained by the availability and accessibility of complete accident sketches from police records. As a result, the findings are not intended for statistical generalization but rather for exploratory and contextual understanding.

Second, the data were collected from documented cases only, without supplementary interviews, sensor-based data, or real-time observations, which may have enriched the analysis. Third, the study does not apply predictive modeling techniques due to the limited volume and structure of the dataset. Instead, it focuses on descriptive and categorical analysis to identify recurring patterns and inform future research directions.

Despite these limitations, the study contributes meaningfully by offering localized, data-informed insights that can support road safety interventions and infrastructure improvements in high-risk corridors. Future research is encouraged to expand the dataset and incorporate advanced modeling techniques for predictive and prescriptive purposes.

4. Research Results

This section presents the findings derived from the analysis of 26 fatal traffic accident sketches provided by the Isfahan Road Police. The data were categorized

and examined based on accident location, type, cause, and contributing factors. The results are presented through tables and figures to highlight patterns and inform data-driven interpretations.

Table *1* summarizes the general characteristics of the analyzed accidents, including the percentage attributed to human error (69.23%), as well as the role of environmental and infrastructural elements

4.1. Accident Causes and Contributing Parties

(30.76%). The data show that in most cases, the primary cause of the accident was attributed to the driver. In a smaller subset, however, factors such as poor signage, lack of guardrails, or road design contributed to the severity or occurrence of the crash.

Table1 .Summary of traffic accidents analyzed based on causes, involved parties, and contributing factors, including transport department failures

Failure of the transport department?	Nationality	Age of Innocent Driver	Age of Guilty Driver	The Cause of the Accident	Accident Type	Innocent Driver Gender	Guilty Driver Gender	Distance from Origin 7
Yes, Guardrail's weakness	Afghanistan	*	50	Inability to control the vehicle	other	*	Male	**6**
Yes, there was no guardrail	Iran	No	60	Deferred to further research	other	Male	Male	**65**
Yes, there was no guardrail	Iran	39	no	Failure to respect the right of way	Front to the left side	Male	Male	**30**
Yes, there was no guard in the middle of the road	Iran	No	60	Deviation to the left	Front to front	Male	Male	**30**
Yes, Guardrail's weakness	Iran	No	49	Inability to control the vehicle	Other	Male	Male	**20**
No	Iran	38	37	A sudden change of direction	Left side to left side	Female	Male	**10**

4.2. Accident Distribution by Road Type

The highest frequency of fatal accidents was observed on the Amir Kabir highway (23.08%), followed by the Isfahan–Shiraz and Isfahan–Tehran routes. These three corridors together accounted for approximately 70% of the total cases analyzed, suggesting the need for targeted safety interventions in these zones.

Percent	Route
23%	**Amir Kabir Freeway (Kashan-Isfahan)**
22%	**Highway (Isfahan-Shiraz)**
19%	**Highway 65 (Isfahan-Tehran)**
36%	**Other routes**

Table2 Accident frequency by route

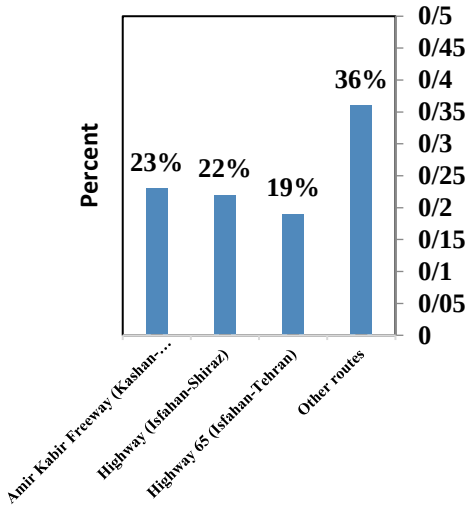

Figure 1 Bar chart based on accident percentage based on four axes of travel

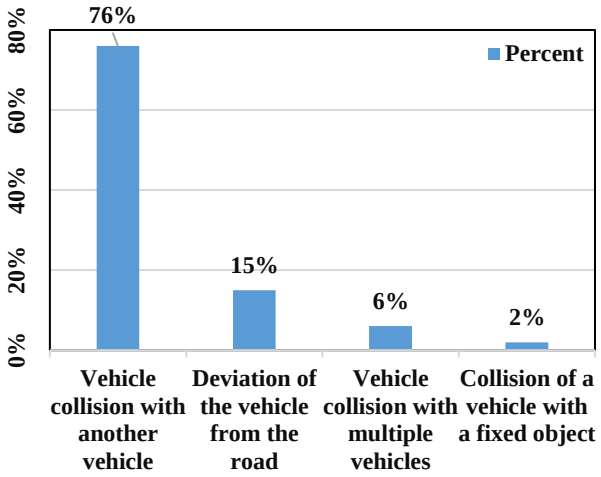

Figure 2 Accident type based on percentage in four different conditions

4.3. Accident Types and Conditions

A substantial portion of fatal incidents involved vehicle-to-vehicle collisions, comprising nearly 50% of the sample. Vehicle deviation and multi-vehicle crashes were also notable. Figure 1 illustrates the distribution of accident types under four distinct environmental or situational conditions. These patterns suggest a need to evaluate driving behavior and road conditions concurrently.

a significant number of accidents occurred during nighttime hours, under low-visibility conditions. Although not all sketches included precise timestamps, the patterns observed raise concern over road lighting and driver fatigue. The nighttime bias aligns with global findings on increased crash risk during reduced visibility periods.

Table3 Accident frequency by accident type

Percent	Type of accident
76%	Vehicle collision with another vehicle
15%	Deviation of the vehicle from the road
6%	Vehicle collision with multiple vehicles
2%	Collision of a vehicle with a fixed object

4.4. Time of Occurrence and Visibility

Figure 3 indicated that

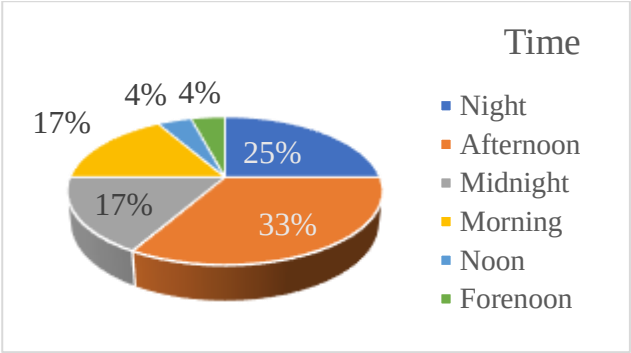

Figure 3 Distribution of fatal traffic accidents by time of day

4.5. Contribution of Human vs. Non-Human Factors

Figure 4 presents the relative contribution of various accident causes. Human-related causes remain dominant, but infrastructural deficiencies such as absence of flexible guardrails or poor road design were cited in approximately one-third of the sketches. These findings emphasize the multifactorial nature of fatal road accidents.

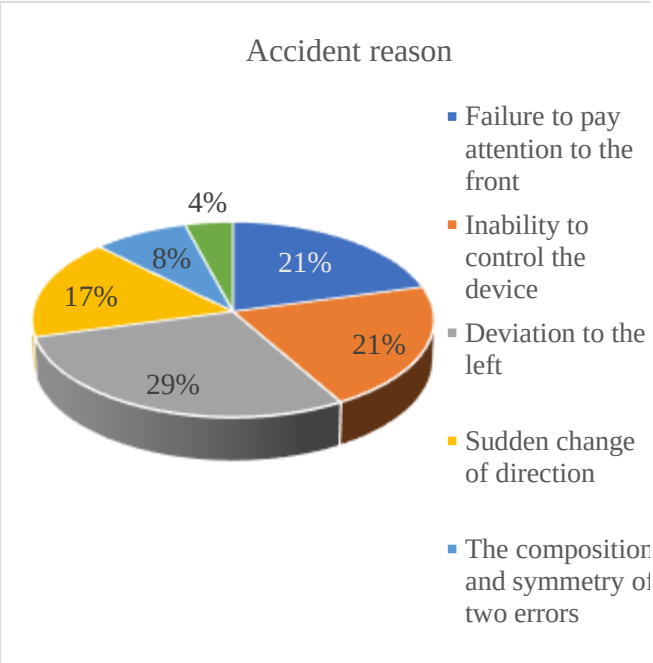

Figure 4 Contribution of factors in the occurrence of accidents

4.6. Contribution of Human vs. Non-Human Factors

4.6.1 Chi-Square Test: Road Type vs. Accident Type

To evaluate whether accident type is associated with specific road types, a chi-square test was conducted based on the categorical data presented in Table 4. The result of the test ($\chi^2 = 3.90$, $p = 0.918$, $df = 9$) indicates no statistically significant relationship between the two variables.

Table 4 Cross-tabulation of Road Type and Accident Type

Accident Type	Amir Kabir	Isfahan-Shiraz	Isfahan-Tehran	Other
Vehicle-Vehicle	4	3	2	4
Deviation	1	2	2	1
Multi-Vehicle	1	1	1	0
Fixed-Object	0	0	1	1

4.6.2 Chi-Square Test: Cause of Accident vs. Accident Type

A second chi-square test explored the relationship between the identified cause of accident and the resulting type of accident. The test result ($\chi^2 = 48.00$, $p < 0.001$, $df = 9$) demonstrates a statistically significant association, suggesting that different causes are strongly linked to distinct accident types.

Table 5 Cross-tabulation of Accident Cause and Accident Type

Accident Type	Failure to Pay Attention	Loss of Control	Lane Deviation	Infrastructure Problem
Vehicle-Vehicle	4	3	2	4
Deviation	1	2	2	1
Multi-Vehicle	1	1	1	0
Fixed-Object	0	0	1	1

4.7. Overlap of Contributing Factors

In addition to identifying individual causes of fatal accidents, the study explored the overlap between three major categories: human factors, environmental factors, and road/infrastructural elements. A Venn diagram (Figure 5) illustrates the percentage

distribution of accident cases involving one, two, or all three categories.

The majority of accidents (49%) were attributed exclusively to human factors, while 42.55% involved a combination of human and environmental elements. Notably, 1.41% of the cases reflected all three factors interacting simultaneously. These overlaps emphasize the multifactorial nature of fatal road accidents and underline the need for integrated safety interventions. Figure 5 adds depth to the earlier chi-square analysis by visually presenting the interaction and co-occurrence of various contributing causes in the dataset.

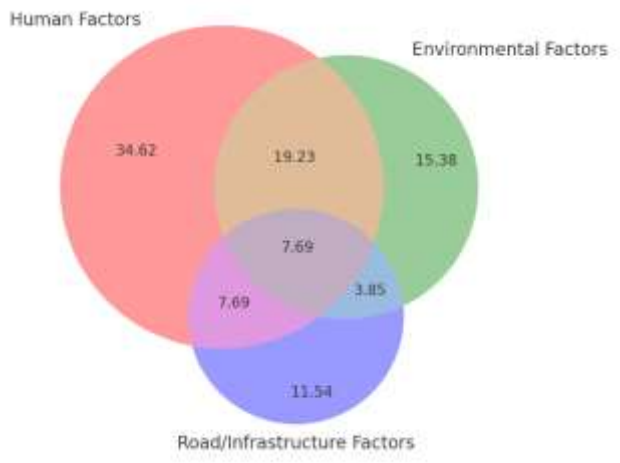

Figure 5 Venn diagram of accident cause overlap based on 26 sketches (in %)

5. Discussion

In this study, using 26 official accident sketches, an attempt was made to present a clear picture of the situation of fatal road accidents in Isfahan province. The findings show that more than two-thirds of these accidents were directly related to human error, especially factors such as fatigue, loss of vehicle control, and lane deviation. This is in line with many previous studies in Iran that consider the role of driver behavior to be prominent in the occurrence of accidents (Yousefifard et al., 2021). However, the role of environmental and infrastructural factors has not been ignored, and in almost one-third of cases, factors such as the absence of guardrails, improper road design, or weak warning signs played a role in the occurrence or severity of the accident (Mansouri et al., 2014).

Based on the geographical distribution of accidents, it was found that highways such as Amir Kabir and Isfahan-Shiraz are among the most accident-prone routes that require urgent interventions (Nasr Isfahani et al., 2024). Statistical analysis also showed that there is a significant relationship between the type of accident and its cause, such that the type of collision (e.g., head-on collision, rollover, or deviation) in relation to the type of factor (human or infrastructure) creates analyzable patterns.

One of the strengths of this study is the use of real data based on official sketches and their analysis with the aim of identifying recurring patterns. However, there are also limitations, including the relatively small sample size and the lack of supplementary data such as interviews or real-time analysis. Nonetheless, this research has been able to provide a basis for designing data-based safety interventions.

It is suggested that advanced analytical methods such as predictive modeling, machine learning algorithms, and spatial analysis (GIS) be used in future research to provide the ability to predict hazardous conditions and design warning systems in addition to analyzing the current situation. Also, expanding the available

data and improving its quality can make analyses richer and more effective.

6. Conclusion and Recommendations

This study investigated the factors affecting the incidence and severity of accidents on intercity roads in Isfahan province. Data from 26 official sketches showed that a high percentage of these accidents were caused by human errors such as fatigue and loss of vehicle control. However, the role of infrastructure factors is also undeniable in about one-third of cases, especially weaknesses such as the lack of safe guardrails or inappropriate route design on busy roads. Roads such as the Amir Kabir and Isfahan-Shiraz highways were among the most dangerous routes that require immediate interventions and engineering review.

The results also show that there is a statistically significant relationship between the type of accident and the cause of the accident, which further highlights the importance of paying attention to designing interventions appropriate to the conditions of each route. Although predictive modeling was not used in this study, the patterns identified can be the basis for designing analytical and future research models. Practical steps like installing standard guardrails, improving road lighting, using clear warning signs, targeted driver training, and utilizing smart technologies in traffic monitoring are among the solutions that can help improve road safety.

In addition to these measures, increasing the accuracy of collecting data from the road surface and using it in macro-decision making can pave the way for further research. By combining this data with machine learning algorithms, tools can be achieved in the future that can identify and control dangerous conditions before an accident occurs. Accordingly, this research emphasizes the need to simultaneously pay attention to human, technical, and environmental factors in reducing road accidents; a holistic approach that both saves lives and takes steps towards sustainable developme

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