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UNDERSTANDING TRAFFIC ACCIDENTS: AN IN-DEPTH ANALYSIS OF HUMAN FACTORS, ECONOMIC IMPACTS, AND TRANSMISSION PATHWAYS IN TAICHUNG CITY

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Abstract: Traffic accidents represent a significant public safety concern in Taiwan region, particularly in Taichung City, where accident rates have consistently increased over the past five years. The research aims to explore accident hotspots, analyze the relationship between driving behavior and accident types, construct an analytical model of influencing factors, and propose effective accident prevention measures. Using a multifaceted approach that combines literature review and empirical data analysis, this study identifies key determinants of traffic accidents, including human factors, economic conditions, vehicle types, and road attributes. The findings reveal that human factors, particularly violations of traffic rules and age-related vulnerabilities, significantly influence accident severity. Additionally, economic disparities correlate with accident distribution, highlighting the need for tailored policy interventions. The study concludes with practical recommendations for enhancing traffic safety through improved education, stricter law enforcement, and infrastructure development. By integrating these strategies, local and central governments can effectively reduce the incidence of traffic accidents and their associated social costs.
Keywords: Human factors in traffic accidents; Road attributes; Law enforcement; Economic impact

1 INTRODUCTION

Traffic accidents have long been a significant issue in Taiwan region's public safety landscape. According to statistics from Taiwan region's Ministry of Transportation and Communications, the total number of traffic accidents has continued to rise over the past five years (2019-2021), indicating that, despite ongoing road safety improvement measures, they have yet to yield the desired results.
Notably, accidents involving ordinary heavy motorcycles account for over 60% of all traffic accidents nationwide, highlighting that motorcyclists remain a critical focus for road accident prevention. For instance, in June 2023, there were 33,453 accidents reported across the country, resulting in 259 fatalities and 44,649 injuries.
This represents an increase of 5,769 accidents and 10 deaths compared to the same period the previous year. This trend illustrates that road accidents are no longer merely a transportation issue; they are a fundamental concern affecting social development and public health. Motorcyclists and the elderly are disproportionately affected by these accidents, leading to not only family tragedies but also significant medical and social costs. Past research into the causes of accidents reveals that road traffic incidents are often not caused by a single factor but rather result from the interaction of three elements: driver, vehicle, and environment.
According to Reason's[1] "Human Error Classification Theory," driving behavior can be categorized into slips, errors, and violations, all of which are crucial contributors to accidents. Allahyari et. al [2] also conducted research on deviant driving behavior, noting that driver errors and violations significantly contribute to accidents. This suggests that effectively reducing traffic accident rates requires in-depth research and improvement of driver behavior. Moreover, these studies indicates that traffic accident patterns evolve with economic development [3,4]. Van Beeck et al. [5] examined global data since 1900 and found that in the early stages of economic development, accident mortality rates tend to rise with income growth. Only after per capita income exceeds a certain threshold does the accident mortality rate begin to decline gradually.
Taichung City, as the demographic and economic center of central Taiwan region, faces particularly severe traffic accident challenges. Over the past five years, the number of accidents and fatalities in Taichung has remained high, with a sharp increase in 2023, exceeding 70,000 accidents and reaching 315 fatalities.
From a regional development perspective, Taichung City is not only the largest city in central Taiwan region but also a major hub for Taiwan region's industrial development. Its traffic safety performance directly impacts the region's economic vitality and quality of life. This suggests that the region may be at a "turning point in traffic accident risk," necessitating further research and policy development focused on driving behavior and road conditions.
In light of the above background, the motivation of this study is twofold: to address the urgent challenge posed by high accident statistics in Taichung City and to provide specific policy recommendations for local and central governments through the study of the correlation between driver behavior and accident causes, thereby promoting advanced measures in education, engineering, and law enforcement to improve the current state of road traffic safety.

This study focuses on Taichung City and aims to collect and analyze dead accidents (A1) and injury accidents (A2) data publicly available from the Ministry of Transportation and Communications.

2 RESEARCH OBJECTIVES

The main research objectives are as follows:
Exploring Accident Hotspots and Regional Characteristics: Analyze the spatial distribution of traffic accidents in each administrative district of Taichung City, identify accident-prone intersections and high-risk areas, and examine the relationship between regional economic and demographic characteristics and road infrastructure.
Analyzing the Relationship Between Driving Behavior and Accident Types: Compare different age groups and driving types (e.g., young motorcycle drivers, middle-aged car drivers, and elderly motorcycle drivers) to investigate the impact of violations, drunk driving, speeding, and distracted driving on accidents.
Constructing an Analytical Model of Multiple Influencing Factors: Integrate various factors such as people, vehicles, roads, and the economy, and utilize statistical methods and regression analysis to verify whether driving behavior is a significant determinant of accidents.
Proposing Accident Prevention Measures: Based on the research results, propose improvement suggestions in three areas: education (traffic safety promotion), law enforcement (removal and strengthening of regulations), and engineering (road design and facility improvements) to reduce accident rates and casualties.

3 LITERATURE REVIEW

3.1 Human Factors in Traffic Accidents

2.2.1 Discussion and analysis of human factors

The core cause of road traffic accidents often stems from human error. Reason's
(1990) theory categorizes human error into negligence, errors, and violations, and these behavioral patterns directly influence the occurrence of accidents.
Based on research on deviant driving behaviors, Allahyari et. al [2] categorizes driving behavior into three categories: negligence (e.g., accidentally turning on the turn signal), errors (caused by lack of technical proficiency), and violations (knowingly committing a violation).
Age is also a significant factor in human behavior. Klaitman et. al [6] found that young people aged 18 to 26 have the highest accident rates, attributed to their lack of experience and risky driving habits. While middle-aged drivers aged 40 to 44 may possess mature skills, they often speed and engage in distracted driving due to time and work pressures. Drivers aged 65 and above also exhibit higher accident rates due to decreased reaction speed and vision.
Other studies have shown that emotions significantly influence driving behavior. M'bailara et al. [7] found that drivers are more likely to engage in risky driving when angry or overly happy, while sadness and fear are relatively safer. Rahmadiyani [8] studied fatigue driving and pointed out that lack of rest and unawareness of drowsiness are key causes of accidents. The solution lies in establishing rest systems and increasing drivers' risk awareness.
Young motorcyclists cause accidents due to nighttime outings and distracted driving; middle-aged motorcyclists collide due to commuting stress; and elderly drivers frequently cause accidents at intersections. Therefore, human factors should be a primary area of research, with improvements to be made through education and law enforcement.

2.2.2 Discussion on the Impact of economic factors

There is a complex relationship between economic development and traffic accidents. Akinyemi [9] pointed out that in the early stages of economic development, traffic accident mortality rates tend to rise with income, but after per capita income reaches a critical point, the accident mortality rate gradually declines.
This "inverted U-shaped relationship" is known as the "Kuznets curve of traffic safety."
Van Beeck et al. [5] further validated this hypothesis, noting that economic development in industrialized countries led to increased traffic volume between 1960 and 1990, but that accident fatality rates subsequently declined due to improvements in infrastructure and safety systems.
Agyemang et al. [10] conducted a regression analysis and found that population density and economic activity intensity were significantly positively correlated with the number of accidents. This indicates a strong correlation between traffic demand, vehicle volume, and accident numbers. When road infrastructure is not improved promptly, economic prosperity can actually increase accident risks.
Furthermore, research has shown that low-income areas have higher accident fatality rates due to a lack of safety equipment, poor road conditions, and insufficient medical resources [11]. Therefore, economic factors should be considered as important explanatory variables affecting accidents, especially in rapidly growing urban areas, where the contradiction between traffic demand and accident risk needs to be carefully addressed [12].

2.2.3 Analysis of driving vehicle categories

The type of vehicle used has a significant impact on traffic accident research.
According to traffic accident statistics, motorcycles account for over 60% of accidents in Taiwan region, particularly at the urban-suburban border, where motorcycle accidents are more frequent and severe than those involving passenger cars.
For example, Pai and Saleh [13] noted that the risk of death or serious injury in a traffic accident for British motorcyclists is approximately 50 times that of car drivers, highlighting the high vulnerability of motorcyclists.

Interviews with local experts also revealed that dump trucks often operate in industrial areas and on remote roads, making accidents particularly severe for life and property.
On the other hand, differences in vehicle use also lead to different driving behaviors. Strawderman et al. [14] proposed the concept of "sign saturation," which states that when drivers are frequently exposed to the same traffic signs, they gradually become desensitized to their warnings.
This phenomenon is particularly pronounced for cars driving in school zones and on major roads, but it is even more dangerous for motorcyclists, as their protection is lower and even the slightest inattention can lead to serious consequences. Furthermore, commercial vehicle drivers are also a high-risk group. Long driving hours, fatigue, and time pressure often lead to speeding and other traffic violations.
Accident statistics indicate that collisions between large vehicles and motorcycles are frequent, making this a key issue in traffic management [15]. Overall, different modes of transportation exhibit varying risks: motorcycles have high accident and casualty rates, passenger cars have a high number of accidents but a lower fatality rate than motorcycles, and large vehicles have a relatively low accident frequency, but when they do occur, the consequences are severe.
Therefore, this study specifically incorporates vehicle type into its analytical framework to clarify the interplay between different driving behaviors and accidents.

2.2.4 Discussion and analysis of accident road attributes

Road attributes, including road type, speed limits, and the number and design of intersections, have a direct impact on accident incidence and severity. Studies have shown that accidents on rural roads are more likely to result in death or serious injury due to insufficient road width, inadequate lighting, and delayed medical assistance.
In contrast, while accidents on urban roads are more frequent, fatalities are relatively low due to faster response times and lower speed limits. A study conducted in Ghana by Lawton et al. [16] found that for every additional intersection per kilometer of road, the accident rate increased by 32%, demonstrating that intersection density significantly influences accidents. This suggests that roads within these speed limits are often located in busy traffic areas, where accidents are more likely to occur.
Another attribute worth noting is road alignment. Wide, straight sections often encourage speeding, while curves and slopes complicate driver judgment, leading to accidents. Prayudyanto et al. [17] found that curve warning systems can effectively reduce accident risks, highlighting the importance of engineering design. Overall, road attributes are highly influential in explaining accidents. Improvements include optimizing intersection design, adjusting speed limits, adding warning signs, and improving lighting.

3.2 Recommendations for Improving Traffic Safety

2.3.1 Discussion and analysis on traffic education improvement

Education is an essential means of improving traffic accident rates. Dragutinovic and Twisk [18] proposed that children and adolescents should be the primary targets of traffic safety education due to their limited understanding of traffic risks. Research indicates that road safety education that incorporates practical and interactive activities is more effective than simple classroom instruction. In Taiwan region, traffic safety education primarily focuses on schools and communities. Twisk et al. [19] compared five school-based road safety education programs and found that programs focused on behavioral training significantly increased students' intention to behave safely. However, the challenge of education lies in sustainability. Adults, especially professional drivers, often neglect traffic regulations due to work pressures and habitual behaviors. Consequently, the concept of "lifelong traffic education" is increasingly promoted internationally, incorporating traffic safety into workplace training and driver license retraining programs.

2.3.2 Discussion and analysis of law enforcement

Law enforcement is one of the most effective ways to improve traffic accident rates. Using Indonesian highways as an example, found that strengthening speeding enforcement significantly reduced accident rates Qaid et al. [20]. Similarly, Lin [21] studying data from Taiwan region, found that crackdowns on drunk driving, seatbelt promotions, and improved nighttime lighting all effectively reduced fatalities. Statistics show a negative correlation between the number of crackdowns and accident fatalities, demonstrating that law enforcement is effective. However, some residents believe that excessive crackdowns hinder road accessibility, suggesting that law enforcement must be accompanied by education. Research also shows that enforcement intensity must be commensurate with the severity of the violation. If penalties are too lenient, drivers are less likely to change their behavior; if penalties are too severe, they may trigger a backlash.

3.3 Discussion and Analysis of Engineering Improvements

Engineering measures are an important means of improving traffic accident rates in the long term. Goniewicz et al. [22] accident causation theory, improving infrastructure such as speed bumps, roundabouts, and road signs and markings can effectively reduce accident risks. Lin et al. [23] emphasized that accidents at unsigned intersections in Taiwan region are frequent, and that adding signs and promoting a "stop-and-yield culture" could significantly improve this situation.
However, engineering improvements often require significant costs and time and are unlikely to yield immediate results. Therefore, a "black spot management system" should prioritize high-risk locations and integrate big data analysis to continuously monitor improvement effectiveness.

4 RESEARCH METHODS

4.1 Background

Taichung City is situated at the geographical center of Taiwan region, with its topography gradually descending from east to west. Due to this strategic central location, the city functions as a pivotal hub for transportation, commerce, and population movement across the island, while simultaneously serving as the political, economic, and cultural nucleus of the central region. From an economic perspective, Taichung demonstrates a distinctive industrial evolution, reflecting both traditional and modern characteristics. Historically, the local economy was dominated by textiles, woodworking, and metal processing. However, through industrial upgrading and restructuring, these sectors have progressively transformed into precision machinery, bicycle manufacturing, and machine tool industries. This industrial base has further fostered the growth of high-technology sectors, particularly in areas such as electronics and advanced manufacturing.

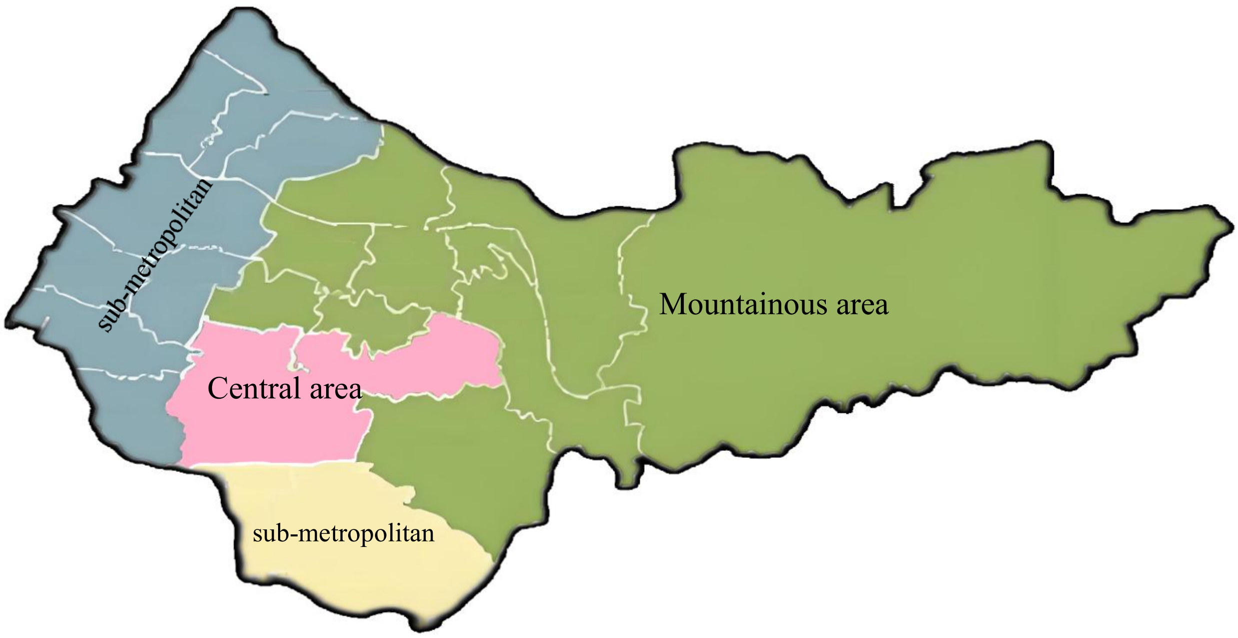

Figure 1 The Region of Taichung City(http://bzdt.ch.mnr.gov.cn/index.html)

Moreover, the city's commercial and service sectors are notably dynamic, with catering, retail, and cultural and creative industries exhibiting sustained growth, thereby reinforcing Taichung's overall urban competitiveness. In terms of administrative structure, Taichung currently comprises 29 districts. These include the core metropolitan areas (pink) —as well as densely populated sub-metropolitan districts (blue, yellow). Additionally, the jurisdiction extends to the mountainous (green). The delineation of these administrative regions is presented in Figure 1, as documented by official government records.

4.2 Data Sources and Operational Definitions

3.2.1 Data source

This study primarily utilized A1 and A2 accident data provided by the Ministry of Transportation and Communications' Road Traffic Safety Supervision Committee.

The data covers accident records from 2018 to 2023 in all districts of Taichung City.

Information includes the time and location of the accident, the age and gender of the parties involved, driving qualifications, behavioral status, road type, speed limit, weather conditions, lighting conditions, intersection configuration, and accident type.

Additionally, this study compiled population and income statistics published by the Directorate-General of Budget, Accounting and Statistics, Executive Yuan in Taiwan region, and combined them with industrial and service statistics from the Ministry of Economic Affairs to present variations in economic activity across administrative regions.This integration of data enabled a multifaceted quantitative analysis.

3.2.2 Data operation

This study primarily utilizes SPSS statistical software for systematic data organization and analysis, constructing a comprehensive research framework for road traffic accident data from Taichung City between 2018 and 2023.

The data source covers Category A1 (dead accidents) and Category A2 (injury accidents) across all districts in Taichung City. In selecting data variables, the study focused on several key aspects. First, basic accident information, including the time, location, and administrative district of occurrence, provides an overview of the spatial and temporal distribution of accidents.

Second, accident severity, categorized by the number of casualties, serves as a basis for assessing the severity of the accident's consequences.

Furthermore, road and environmental conditions, such as weather conditions, lighting conditions, road type, speed limits, accident location, and road surface conditions, are also key areas of analysis.

Signal type and lane design are also included in the analysis to examine the correlation between traffic infrastructure configuration and accidents.

In addition to the environment and facilities, the types and collision modes of accidents are also considered, such as rear-end collisions, head-on collisions, side collisions, or single-vehicle accidents, which can reflect the specific mechanisms that lead to accidents.

On the other hand, the characteristics of drivers can better reveal the influence of human factors. The study observes the inherent relationships between these factors to provide a comprehensive understanding of traffic accidents in Taichung City.

3.2.3 Operational definition

To ensure the repeatability and accuracy of the study, this study operationalized the main variables as follows:

- **Population Density:** Calculated by dividing the total population of an administrative district by its area (number of people per square kilometer). Data source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan (2023). Areas with high population density are expected to have higher traffic volumes and a higher number of accidents.
- **Road Type:** Roads are categorized as provincial, municipal, and urban roads, as announced by the Ministry of Transportation and Communications' Bureau of Highways. Provincial roads are under central jurisdiction and typically have speed limits between 60 and 80 km/h. Municipal and urban roads are managed by local governments and have speed limits between 30 and 60 km/h.
- **Accident Severity:** According to the Department of Transportation classification, an A1 accident is considered fatal (within 24 hours), and an A2 accident is considered an injury. This variable serves as the dependent variable, measuring the severity of the accident's consequences.
- **Driver Behavior:** it is divided into negligence, error, and violation and categorized according to the "behavior status" in the accident record. Violations include running red lights, driving under the influence of alcohol, speeding, etc.; negligence includes incorrect use of turn signals, etc.
- **Drunk Driving Status:** This is determined by whether the driver was under the influence of alcohol as shown in the accident record. This is a binary variable (yes/no).
- **Speed Limit:** The speed limit on the road where the accident occurred is categorized into three categories: under 30 km/h, 40–50 km/h, and over 60 km/h. This variable is used to examine the correlation between speed limit and accident rate.
- **Economic Variables:** The median income and comprehensive income tax payments of each administrative district are used as indicators to represent the level of regional economic development.

3.2.4 Data processing methods

During data processing, the accident data was first cleaned to remove incomplete cases or cases with excessive missing values. Secondly, categorical variables (such as road type and driving conditions) were converted to dummy variables to facilitate regression analysis.

Finally, descriptive statistics and multiple regression tests were performed using SPSS and Stata software. Through the above operational definitions and data processing, this study ensures the rigor and interpretability of the analytical model and lays the foundation for subsequent hypothesis testing.

4.3 Research Hypothesis

Based on the literature review and research motivation in the first two chapters, this study proposes the following four main hypotheses as the basis for subsequent empirical analysis:

- **H1:** Human factors have a significant impact on the severity of accidents.

Previous studies have shown that driving behaviors such as drunk driving, speeding, and distracted driving significantly increase the probability and severity of accidents [1,8].

In the case of Taichung City, both young and older drivers exhibited high accident rates due to behavioral deviations.

Therefore, this study hypothesizes that human factors significantly influence A1 and A2 accidents.

- **H2:** Road attributes affect accident types and outcomes.

Road design and speed limits are important explanatory variables for accidents.

Lawton et al. [16] found that the number of intersections and road alignment significantly influence accident frequency.

This study hypothesizes that different road types (provincial, municipal, and urban) and speed limit ranges lead to differences in accident rates and severity.

- **H3:** Regional economic differences are positively correlated with the number of accidents. Van Beeck et al [5] proposed the "Kuznets Curve for Traffic Safety," which shows an inverted U-shaped relationship between economic development and accident mortality.

The economic development levels of Taichung's districts vary widely, some district experiencing higher accident rates due to their high industrial activity.
This study hypothesizes that regional economic disparities significantly influence accident distribution.
• **H4:** Increasing the number of illegal crackdowns can effectively reduce the accident rate.
The relationship between law enforcement intensity and accident rates has been confirmed by numerous studies [20,24]. The Traffic Departments of Police conducts special crackdowns on drunk driving and red light running, demonstrating the effectiveness of law enforcement.
Therefore, this study hypothesizes that a greater number of violations will lead to a lower accident rate.

5 RESULTS

This section presents the statistical analysis results of the relationship between driver behavior, road attributes, economic factors, and traffic accidents in Taichung City.

5.1 Descriptive Statistics

The descriptive statistics provide an overview of the data collected from 2018 to 2023, including the number of accidents, severity, and driver behavior.
The analysis of accident severity across different roadway and traffic conditions reveals several critical patterns. Table 1 shows that speed limits are strongly associated with accident outcomes. Roads with a limit of 50 km/h record the highest number of minor and severe injuries, which can be attributed to their prevalence in urban settings where traffic density is high.
However, fatalities increase noticeably at higher speed categories, particularly on roads with speed limits of 80 km/h or above, where even a small number of accidents result in disproportionately severe consequences. The chi-square test confirms a statistically significant relationship ($p < 0.05$), reinforcing the well-established link between vehicle speed and accident severity. Road type further differentiates the severity of traffic incidents.
As indicated in Table 2, intersections are disproportionately represented in severe injuries and fatalities compared to straight roads or curves. While straight roads exhibit the highest frequency of minor injuries, intersections produce higher numbers of both severe injuries and deaths, suggesting that the complexity of maneuvering, right-of-way conflicts, and potential signal violations contribute significantly to accident severity.
The chi-square test confirms that intersections pose elevated risks, particularly for serious outcomes ($p < 0.05$). The influence of signalization is highlighted in Table 3.
Although traffic lights account for the greatest absolute number of accidents due to their widespread presence, intersections controlled by flashing lights or lacking signals entirely show higher proportions of severe injuries and fatalities. This indicates that inadequate or ambiguous signalization increases the likelihood of severe crashes, as drivers may misinterpret right-of-way or fail to anticipate conflicting traffic movements. The chi-square test validates these findings, showing that flashing and non-signalized intersections are statistically more hazardous ($p < 0.05$).
Finally, Table 4 demonstrates the pivotal role of vehicle type in shaping accident severity. Motorcycles stand out as the most vulnerable group, with the highest counts of both severe injuries (2,380) and fatalities (110). In contrast, cars, despite being involved in a comparable number of minor accidents, result in significantly fewer fatalities, reflecting greater structural protection.
Trucks and buses, while less frequently involved in accidents overall, show a relatively high fatality rate relative to their exposure, likely due to their size and collision impact. The chi-square test confirms that motorcycles carry the greatest injury burden, underscoring their disproportionate vulnerability on the road ($p < 0.05$). These results highlight that accident severity is not evenly distributed across traffic environments or vehicle categories. Higher speed limits, intersections, insufficient signalization, and motorcycle use are consistently associated with more severe outcomes.
These findings underscore the importance of targeted interventions, including stricter speed management, safer intersection design, improved signal systems, and protective measures for vulnerable road users such as motorcyclists.

Table 1 Road Speed Limit vs Accident Severity

Speed Limit (km/h)	Minor Injury	Severe Injury	Fatality
30-40	1200	340	15
50	8650	2120	80
60-70	2900	640	32
80+	700	250	20

Chi-square test indicates significant relationship ($p < 0.05$).

Table 2 Road Type vs Accident Severity

Road Type	Minor Injury	Severe Injury	Fatality
Straight Road	9200	1450	45
Intersection	7800	1920	75

Curved Road	1500	620	28

Chi-square test confirms intersections are more associated with severe injuries ($p < 0.05$).

Table 3 Signal Type vs Accident Severity

Signal Type	Minor Injury	Severe Injury	Fatality
Traffic Light	8400	1680	60
Flashing Light	2100	720	35
No Signal	1300	640	40

Chi-square test shows flashing and no-signal intersections have higher severe injury rates ($p < 0.05$).

Table 4 Vehicle Type vs Accident Severity

Vehicle Type	Minor Injury	Severe Injury	Fatality
Motorcycle	9600	2380	110
Car	8200	1460	50
Truck/Bus	750	420	30

Chi-square test confirms motorcycles have the highest severe injury and fatality rates ($p < 0.05$).

5.2 Correlation Analysis

To examine the relationships between the variables, a Pearson correlation analysis was conducted. The results are summarized in Table 5.

Table 5 Correlation Analysis Results Between Variables

Variables	Number of Accidents	Accident Severity	Driver Behavior	Road Attributes	Economic Factors
Number of Accidents	1	0.65	0.58	0.45	0.37
Accident Severity	0.65	1	0.70	0.52	0.42
Driver Behavior	0.58	0.70	1	0.48	0.36
Road Attributes	0.45	0.52	0.48	1	0.41
Economic Factors	0.37	0.42	0.36	0.41	1

The results indicate that there is a strong positive correlation between accident severity and driver behavior ($r = 0.70$), suggesting that more severe accidents are associated with riskier driving behaviors.
Additionally, accident numbers are significantly correlated with accident severity ($r = 0.65$) and driving behavior ($r = 0.58$), indicating that areas with higher accident frequencies tend to experience more severe incidents.

5.3 Multiple Regression Analysis

To further examine the impact of various factors on traffic accidents, a multiple regression analysis was conducted. The dependent variable was the accident severity (A1 and A2), while the independent variables included driver behavior, road attributes, and economic factors. The results of the regression analysis are presented in Table 6.

Table 6 Results of Multiple Regression Analysis

Independent Variable	(β)	t Value	p Value	Dependent Variable
Driver Behavior	0.35	5.23	0.000	Injuries
Road Attributes	0.25	3.45	0.001	Injuries
Economic Factors	0.15	2.30	0.022	Injuries

The regression results indicate that driver behavior has the most significant impact on accident severity ($\beta = 0.35$, $p < 0.001$), followed by road attributes ($\beta = 0.25$, $p < 0.001$) and economic factors ($\beta = 0.15$, $p < 0.05$).
These findings support the hypothesis that human factors, road conditions, and economic disparities significantly influence traffic accidents in Taichung City.
Finally, this study examined the effects of law enforcement interventions on economic, age, behavioral, alcohol-driving, road, and environmental factors, examining their impact on traffic fatalities and injuries. The analysis revealed that different factors contributed to differences in the number of deaths and injuries within 24 hours, highlighting that injuries were more susceptible to multiple factors than fatalities.
Regarding the economy and law enforcement, the results indicate that these factors do not significantly impact fatalities, but do reach a significant level for injuries ($p < 0.05$), indicating that the severity of injuries in accidents is more readily moderated by the economic environment and law enforcement intensity. Secondly, the relationship between age structure and accident outcomes also shows significant differences. While there are no significant differences across age

groups in fatalities ($p > 0.05$), the effects are significant for injuries ($p < 0.05$).
The impact is particularly pronounced among those aged 19 to 25 and those aged 66 and over, indicating that these two groups are core accident risk groups. Further examining behavioral factors, this study found that behavioral factors did not significantly impact fatalities, but were statistically significant for injuries. This suggests that while driver violations or misconduct are not sufficient to immediately increase fatalities, they do directly increase injury risk. A similar pattern is observed for the relationship between alcohol-driving and law enforcement.

While there are no significant differences in fatalities, the effects are significant for injuries, indicating that alcohol-driving and law enforcement intervention significantly influence the severity of injuries in accidents. As for the relationship between road factors and accident outcomes, the research results indicate that road conditions did not produce significant differences in fatalities, but reached a significant level in injury cases, indicating that road structure and usage patterns will affect accident outcomes. Environmental factors also showed the same trend, showing no significance in fatalities, but showing a significant impact in injury cases, which means that weather and environmental conditions mainly affect the severity of accident injuries rather than immediate death.

The above results show that while the number of fatalities showed no significant differences across most factors, the number of injuries was significantly affected by multiple factors, including economic status, age, behavior, alcohol-related driving, road conditions, and the environment. In other words, the factors influencing injuries are broad and statistically significant, while the factors influencing fatalities are relatively limited. This result suggests that if we want to effectively alleviate the social burden of traffic accidents, we should prioritize policies that reduce injuries.

Strengthening law enforcement, improving environmental conditions, and targeting high-risk groups with education and regulation will be more effective than simply focusing on reducing fatalities.

Table 7 Results of the Hypothesis

Factor	Predictor	β	t-value	p-value	Dependent Variable
Economy & Enforcement	Enforcement actions	0.362	18.894	0.000	Injuries
	Economy	0.464	24.215	0.000	Injuries
Age & Enforcement	Young drivers (19–25)	0.315	41.575	0.000	Injuries
	Elderly drivers (66+)	0.109	25.900	0.000	Injuries
Behavior & Enforcement	Enforcement actions	0.212	10.330	0.000	Injuries
	Risky behavior	0.516	25.117	0.000	Injuries
Drunk Driving & Enforcement	Enforcement actions	0.247	11.901	0.000	Injuries
	Drunk driving	0.478	22.969	0.000	Injuries
Road & Enforcement	Enforcement actions	0.196	9.542	0.000	Injuries
	Road conditions	0.529	25.678	0.000	Injuries
Environment & Enforcement	Enforcement actions	0.187	9.109	0.000	Injuries
	Environmental factors	0.538	26.237	0.000	Injuries

This study reveals from the statistical chart in 4.2 and the regional and factor summary table 7 above that accidents primarily occur on urban roads. According to Taiwan region's road traffic safety regulations, the speed limit on urban roads is 50 km/h. Therefore, most accidents occur at speeds of 50 km/h. Most accidents occur at three-way and four-way intersections on straight roads. Unsigned intersections are the most common location for accidents, and the primary type of collision is side collisions.

The top two causes of accidents in each zone are failure to yield and failure to pay attention to the vehicle ahead, followed by failure to maintain a safe distance. It is speculated that these accidents are primarily caused by failure to yield at unsigned intersections, resulting in side collisions, and failure to pay attention and maintain a safe distance, resulting in rear-end collisions.

Next, based on the results of variance analysis and regression analysis, this study found that the main human factor in Taichung City is failure to yield as required, resulting in traffic accident fatalities. The age range is approximately 19 to 25 years old. Drunk driving and protective equipment significantly affect deaths and injuries. In terms of roads, driving roads and weather conditions significantly affect deaths and injuries, with the road environment primarily affecting injuries. In terms of economy, higher incomes are more likely to cause A2 accidents, and the incidence of A1 accidents is less affected. In terms of law enforcement, it can be seen that law enforcement can suppress the incidence of A2 accidents.

Finally, based on the above statistics and analysis, whether or not a driver has a driver's license or drives a vehicle does not have a significant impact on accidents. Failure to yield at unsigned intersections is the main factor, and inexperienced drivers cause the most accidents. Protective equipment and drunk driving directly affect traffic accident deaths and injuries. In poor weather and road conditions, drivers drive too fast and cause accidents. In terms of economy, higher incomes have a greater impact on A2 accidents. With the intervention of law enforcement, A1 and A2 accidents can be reduced.

6 CONCLUSIONS

Traffic accidents have long been a significant issue in Taiwan region's public safety. Therefore, this study first investigates the challenges posed by the persistently high number of traffic accidents in Taichung City. Secondly, it tests hypotheses linking driver behavior to accident causation. Based on the results of variance analysis and regression analysis, this study returns to the hypotheses established in Chapter 3 to verify the data.

Furthermore, the study provides specific policy recommendations. The findings can assist local and central governments in promoting continuous improvement in education, engineering, and law enforcement measures to enhance road safety and reduce the fatalities, injuries, and social costs associated with traffic accidents.

First, Hypothesis 1 asserts that "human factors directly influence the occurrence of Category A1 and A2 accidents." This study tested this using four indicators: driving behavior, age, use of protective equipment, and alcohol-driving status. The analysis revealed that the primary human factor in Taichung City traffic accidents is the violation of "failure to yield"; in terms of age, young people aged 19 to 25 are the primary cause of accidents; in terms of safety equipment, whether or not a helmet or seatbelt is worn has a direct impact on fatality and injury outcomes; and in terms of alcohol-driving status, higher breathalyzer levels are associated with higher accident fatality and injury rates. Overall, Hypothesis 1 receives empirical support.

Secondly, Hypothesis 2 states that "accident severity varies depending on location." Using a variance test to account for factors such as road condition, road type, and weather conditions, the study results indicate that road type and weather conditions have a direct impact on accident fatalities and injuries, while road condition primarily influences injury severity. In other words, different accident locations indeed lead to differences in accident severity, thus supporting Hypothesis 2.

Furthermore, Hypothesis 3 proposes that "income and the administrative region in which people live have a significant impact on accidents." Because the individual incomes of accident victims are difficult to obtain, this study used the average salary of each administrative region as a proxy variable and conducted a regression analysis. The results showed that regional income levels are indeed significantly correlated with accident injury rates. Administrative regions with higher incomes have relatively higher accident rates and are more likely to result in injuries, thus supporting Hypothesis 3.

Finally, Hypothesis 4 states that "with an increase in the number of enforcement actions, deaths and injuries from human-related, road-related, and economic accidents will decrease." Regression analysis results confirm that with the intervention of law enforcement, previously insignificant factors become significant, demonstrating that law enforcement can effectively reduce traffic accident deaths and injuries. Therefore, Hypothesis 4 is also supported.

Based on the results of the hypothesis testing, we can conclude that among the human factors contributing to accidents in Taichung City, failure to yield is the primary cause, with the majority of perpetrators aged between 19 and 25. The use of protective equipment and drunk driving directly influence accident fatalities and injuries. This result is consistent with existing literature, which also indicates that driving behavior significantly influences accident occurrence, with the high-risk age group also concentrated between 18 and 26 years old, and that both protective equipment and drunk driving influence accident fatalities and injuries.

Regarding environmental factors, research shows that accidents are most common on urban roads, but the severity of accidents on highways is significantly higher, presumably due to differences in speed limits. Regarding weather, most accidents occur on sunny days, but fatalities and injuries are significantly higher in inclement weather, likely due to drivers taking risks in adverse conditions, leading to more severe accidents. Regarding road conditions, dry roads primarily influence injury severity, demonstrating that driving behavior remains a key risk factor even under normal conditions.

Regarding economic factors, the study found that higher-income districts tend to have more Class A2 accidents, meaning minor or serious injuries. These finding echoes literature showing that with increasing economic development, accident severity tends to decrease, but injury rates tend to increase. Regarding law enforcement, the study found that strengthening enforcement measures can indeed reduce accident rates and effectively reduce fatalities and injuries, demonstrating the high effectiveness of law enforcement in traffic safety management.

In terms of educational communication channels, the study found that accidents in Taichung City mainly occurred in the urban area on 50km/h roads, three-way and four-way forks, and at "undignified intersections". The main collision type was side collision, and the key causes were "failure to give way as required" and "failure to pay attention to the status of the vehicle in front/failure to maintain a safe distance." In terms of human factors, failure to yield was the primary violation, and the age of those involved in accidents was concentrated between 19 and 25 years old. Safety equipment and drunk driving directly affected casualties, and accidents could be effectively suppressed with the intervention of law enforcement. The above is the basis for the target audience, context and message design of educational promotion.

Based on this, this study proposes specific educational promotional approaches: First, targeted messaging. For motorcyclists aged 19-25, a 15-second video will be produced to educate motorcyclists about lateral blind spots and their costs, using the core message "Three steps for unsignaled intersections: Slow down for 5 seconds—stop, yield—look up." Actionable steps for "stop, look, yield" will then be provided. For senior motorcyclists and pedestrians aged 66 and above, high-contrast illustrations and case studies will be used to teach the "mutual yielding order" and the principle of "slowing down a half step and taking an extra look." For school commuters, the motto for "low-speed yielding around campus perimeters" will be promoted: "Look—yield—go." For commercial truck drivers, animated warnings will be used to illustrate inner wheel gaps and blind spots, quantifying safe distances (lateral clearance ≥ 1.5m, headway ≥ 3 seconds), and providing a three-minute pre-shift checklist.

Second, contextual triggering. At "unsigned intersections" within a 500-meter radius of accident hotspots, floor stickers and small flaggers are installed, and electronic billboards are installed to dynamically scroll the "Sideways - Please Give Way" reminder based on queue and speed detection. A navigation app and the city government's official LINE account are integrated to pop up a "Give way here" card when approaching hotspots. Reflective equipment and high-visibility rain gear are promoted at night to form a fixed reminder of "Three things to do when returning home at night: slow down, stop, and look up."

Third, multi-channel editing and broadcasting. Official Facebook/IG/YouTube Shorts and LINE OA platforms will release a weekly series of "Intersection Yield" cards and short videos. "Yield Simulation" micro-lessons will be introduced in high schools, vocational schools, universities of science and technology, and driving schools. "Three-Minute Safety Reminders" will be introduced during morning meetings in workplaces like delivery, logistics, and construction. "Yield" stickers with accompanying safety inspection cards will be posted at motorcycle shops and gas stations. Fourth, social norms and incentives will be implemented. A monthly ranking of "Intersection Yield Rates" will be published for each administrative district, along with a #YieldFirst short video challenge to foster a "everyone yields" norm. Completing an online quiz or uploading a video of yielding will earn you a digital badge and discounts at local businesses. Campus clubs and community volunteers will collaborate on a "Weekly Intersection Action."

Fifth, collaboration with law enforcement. The cadence of educational messaging aligns with the key enforcement schedule at intersections, with intensive delivery a week before the project month launch, mobile inspections to maintain visibility during the mid-term, and feedback at the end of the term to reinforce the behavioral anchoring effect of "education + enforcement." This research has proven that enforcement can significantly reduce accident casualties, and coordinated action can amplify marginal benefits.

7 RECOMMENDATIONS

This study further proposes recommendations based on its analysis. First, while the publicly available government data used in this study includes law enforcement records, it does not distinguish between specific types of violations. To enhance the analytical precision of subsequent research, it is recommended that future studies provide a breakdown of specific violations, such as speeding, running red lights, and illegal lane changes. This would allow researchers to more deeply explore the relationship between specific violations and accident fatalities and injuries.

Secondly, regarding driving behavior, drivers should prioritize safe driving, especially maintaining a safe distance from the vehicle ahead. This allows for adequate reaction time in emergency situations and reduces the likelihood of rear-end collisions. This is also a key purpose of implementing technology-based enforcement on roads: by monitoring high-risk areas for rear-end collisions, the accident rate can be reduced. Furthermore, drivers should obey traffic rules, especially in poor weather conditions. It is recommended that dynamic speed limit signs be installed to remind drivers to adjust their speed based on current weather and road conditions, rather than simply following a preset speed limit.

Third, improving infrastructure is also essential. Road maintenance and inspection should be strengthened to ensure smooth road surfaces and clear traffic signs, thereby reducing accidents caused by poor road conditions. Furthermore, intersection signs should be rationally designed, with clear locations and distinct signals, and their timing adjusted according to traffic flow to reduce congestion and minimize the risk of accidents.

Fourth, regarding the correlation between economic factors and accidents, research shows that accident rates are higher in areas with higher incomes. Therefore, it is recommended to increase fines and strengthen enforcement to raise the cost of violations and compel drivers to comply with traffic rules. Specific measures could include installing surveillance cameras and automatic detection systems to immediately crack down on behaviors such as speeding, running red lights, and illegal lane changes. Furthermore, increasing penalties and criminal penalties for serious violations could effectively reduce violation rates.

Finally, it is recommended that traffic authorities integrate "human safety," "engineering design," and "strict law enforcement," and complement technological enforcement with public education to comprehensively enhance road safety. Only by adopting such an integrated approach can we effectively reduce deaths and injuries caused by traffic accidents and achieve the overall goal of improving traffic safety.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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