Received: 12 Aug. 2025; Revised: 07 Nov. 2025; Accepted: 26 Nov. 2025
https://doi.org/10.22306/al.v13i1.755

Developing statistical models to analyze traffic accidents and estimate their economic costs in Jordan

Ahmed Hadi
Civil Engineering Department, University of Samarra, Samarra, 34010, Iraq,
Ahmed.ha.m@uosamarra.edu.iq (corresponding author)
Raed Abdullah Hasan
Civil Engineering Department, University of Samarra, Samarra, 34010, Iraq,
Raed_hasan@uosamarra.edu.iq
Ahmed D. Abdulateef
Civil Engineering Department, University of Samarra, Samarra, 34010, Iraq,
Ahmed.d.abd@uosamarra.edu.iq
Mustafa Mohammed Ihsan
Civil Engineering Department, University of Samarra, Samarra, 34010, Iraq,
Moam8523@gmail.com
Abeer Ahmed Azzawi
Civil Engineering Department, University of Samarra, Samarra, 34010, Iraq,
Eng.abeer@uosamarra.edu.iq

Keywords: traffic accidents, traffic safety, driver behaviour, traffic accidents cost, accident prediction models.
Abstract: This study investigates the behavioral and situational determinants that disrupt the efficient flow of road traffic in Jordan, framing the issue within the broader discipline of transport logistics and flow management. Official crash data obtained from the Public Security Directorate and cost records from local insurance companies were utilized to develop twelve multiple linear regression models that quantify the relationship between human factors and interruptions in traffic, informational, and financial flows. Six models examined the frequency and severity of accidents, while another six analyzed their associated economic impacts. The modeling results identified a consistent set of influential predictors most notably failure to take necessary driving precautions (X8), violation of traffic priorities (X9), and lane misuse (X4) that significantly contribute to both accident occurrence and the resulting financial losses. Most models achieved R^2 values exceeding 0.95, indicating a strong relationship between behavioral inefficiencies and breakdowns in overall road logistics performance. The findings emphasize that driver behavior represents a primary bottleneck in the mobility and cost flow system, directly influencing logistical efficiency across the transport sector. The study highlights the necessity of integrating traffic safety with logistics management by developing preventive strategies, improving regulatory enforcement, and enhancing driver awareness programs. Future research is encouraged to include environmental, temporal, and infrastructural variables to establish a more comprehensive logistics-based framework for understanding and mitigating crash dynamics in Jordan.

1 Introduction

Traffic accidents represent one of the most critical challenges to public safety and sustainable development worldwide particularly in developing countries experiencing rapid increases in vehicle ownership and unplanned urban expansion. From a logistics and mobility-flow perspective, road accidents disrupt the smooth flow of people, goods, and services, leading to severe inefficiencies in transport networks. Among the key determinants, driver behavior remains the dominant factor influencing accident frequency and severity, directly contributing to high accident rates and consequent losses in human life, material resources, and logistical performance [1]. The Hashemite Kingdom of Jordan is one of the countries that is suffering from an increasing burden of traffic accidents, as these accidents directly affect lives, property and infrastructure, as well as their long-term economic and social repercussions.

In light of this reality, there is an urgent need for a careful and integrated study of the problem of traffic accidents, in terms of their size, causes and costs, in order to reach scientific and practical solutions that limit their effects [2]. From this point of view, this research comes to shed light on the traffic reality in Jordan, through a comprehensive analysis of the recorded traffic accident data, which was collected from the competent authorities and includes the total number of accidents, the number of deaths resulting from them, and the number of injuries classified as severe, medium, and simple. The data also included an accurate classification of the causes.

In this study, SPSS was employed to conduct advanced quantitative analyses, aimed at understanding the relationships between the different variables affecting incidents. The linear regression method was used to build mathematical models that explain the behavior of the data, where six different models were developed based on the independent variables associated with the causes of the accidents, and the best model was chosen from them based on the highest value of the coefficient of determination (R^2), which reflects the strength of the model in interpreting the variation in the data [3,4]. These models were not limited to predicting the number of accidents, but the analysis extended to calculating the economic costs associated with these accidents, which include the costs of deaths, injuries of all kinds, and material damage. Six additional models have been built to represent the cost of traffic accidents, using the same methodology, in order to arrive at a comprehensive visualization that can be used by decision makers to estimate the expected economic losses as a result of accidents, to guide preventive policies and to invest in improving traffic infrastructure and safety.

The significance of this research lies in its dual contribution: it not only describes the existing traffic situation and analyzes the behavioral causes of accidents, but also establishes quantitative, data-driven models capable of predicting accident occurrences and their economic costs. From a logistics and transportation management standpoint, these models enhance the understanding of how disruptions in traffic flows affect the overall efficiency of mobility systems and resource allocation. Moreover, the study provides a scientific framework that integrates statistical analysis with mathematical modeling, supporting decision-makers in optimizing traffic-flow management, improving road-safety logistics, and formulating evidence-based transport policies.

The findings of this research represent a scientific reference that can be built upon in future studies, and are a key pillar for the development of national strategies aimed at improving the reality of traffic safety in Jordan, and reducing the human and material losses incurred by the state and society as a result of this worsening phenomenon.

2 Literature review

Traffic accidents are a contemporary societal issue. According to the World Health Organization (WHO), in 2023, traffic accidents claimed approximately 1.35 million lives and injured between 20 to 50 million people [5]**.** The majority of injuries sustained in head-on crashes are sustained by the drivers of the cars involved while sliding and rolling over of vehicles are the primary causes of passenger deaths [6].

Accidents are typically categorized into three distinct types: ‘‘fatal”, ‘‘severe”, and ‘‘slight”. Fatal crashes, defined as accidents resulting in the death of one or more individuals, have a profound global impact. The research underscores this, noting that on average, 1.35 million people perish annually in traffic accidents [7]. A fatal accident is the most severe kind of accident and results in at least one death. Some deadly accidents result in the victim’s immediate passing, while others cause the victim’s death during the next thirty days. This definition, road crash death within 30 days of the crash, is followed by 80 of the 178 countries. A fatal accident may produce legal complexities for the motorists involved in collisions and the penalty will depend on the level of negligence on the part of the other driver. On the other hand, a non-fatal accident causes injuries only and does not result in either an immediate or an eventual death. Moving further a major accident is one that not only causes physical injuries but also considerable damage to vehicles involved in the crash as well as damage to road infrastructure such as barriers, traffic signals, street light poles, etc. [8-10].

Road accident data is classified based on severity. The most severe or Serious accidents refer to incidents that culminate in substantial injuries, non-fatal which may result in such accidents which include fractures, concussions, crushing, severe cuts and lacerations, severe general shock, and other injuries that require emergency medical treatment. The severity of these accidents is typically assessed based on the number of individuals injured and the extent of direct property damage incurred resulting in deaths and serious injuries while minor accidents are characterized by less severe injuries or only vehicle/property damage. Also, a minor road accident is the least severe of all road accidents and causes only minor bruises or sprains. An injured person is hospitalized for less than 12 hours [11-13].

Roadway conditions, encompassing aspects such as traffic congestion and the state of the pavement, play a pivotal role in the incidence of accidents. Research has elucidated an inverse correlation between traffic congestion and the frequency of accidents, while the condition of the road surface is also found to significantly influence the occurrence of accidents [14-16]**.**

Numerous studies have investigated the relationship between environmental, infrastructural, and behavioral factors in shaping the frequency and severity of road accidents. Table 1 summarizes the most relevant research, highlighting the variety of analytical approaches, datasets, and findings across different regions. This synthesis clarifies the methodological trends and gaps that justify the integrated approach adopted in the present study.

As shown in Table 1, most previous studies have focused on behavioral, environmental, and infrastructural determinants of road accidents, with limited attention given to the economic consequences or the integration of cost–frequency relationships. Building upon these findings, the present study employs officially verified datasets from Jordan to develop statistically validated regression models that link accident characteristics with their associated economic costs. This approach aims to provide a practical and evidence-based framework to support decision-making processes, improve road safety policies, and reduce both human and financial losses within the national transport system.

Table 1 Summary of selected previous studies on factors influencing traffic accidents

No.	Focus / Data Type	Method / Model Used	Key Findings	Research Gap / Limitation
[17-19]	Meteorological, roadway, and driver factors	Correlation and regression analysis	Weather, pavement condition, and human factors jointly affect accident frequency and severity	Most studies isolate variables; few integrate environmental and behavioral dimensions
[20,21]	Road condition & driving behavior	Bayesian classifier, ML	Bayesian models effectively predict risky driver behavior and pavement hazards	Focused on algorithm accuracy, not economic impact
[22,23]	Road design, economic indicators	Linear & logistic regression	Regression effectively links design improvements to lower accident rates	Limited contextual validation in developing countries
[24,25]	Police and behavioral data	Statistical modeling / policy review	Weak enforcement significantly increases accident frequency	Did not model cost or injury severity quantitatively
[26,27]	Driver characteristics & socio-economic context	Comparative analysis	Driver behavior and socio-economic traits drive accident risk	Few localized or Jordan-specific empirical models

Note: Reference numbers correspond to the studies listed in the References section [17-27].

3 Methodology

To achieve the research goals, the available data were collected from the General Security Department through the Jordan Traffic Institute (JTI) for the years 2016 to 2023, which include a huge amount of data such as the total number of accidents, fatalities, injuries, and their causes. The study focuses on analyzing, estimate, and identifying the causes that most affect the occurrence of accidents, and then conclude mathematical models using the linear regression method gained from SPSS statistical program, which is a well-known program with its many capabilities in the field of statistical analysis by adopting the highest value (R^2) among the proposed mathematical models.

As pointed out the causes of traffic accidents is essential for developing countermeasures that can effectively reduce accident rates, assuming these measures are properly implemented. The study also examined the economic consequences of traffic accidents in Jordan, encompassing both human and property-related losses. It estimated the cost of a single fatality and a single injury, then calculated property damage costs, leading to the determination of the overall financial burden.

The objective was to identify the most influential factors contributing to traffic accidents and their associated costs from a range of possible causes. To achieve this, the linear regression coefficient was employed, as it effectively highlights the key variables impacting the total number of accidents. In a simple linear regression model, this coefficient is used to assess the extent to which each independent variable influences the dependent variable by quantifying both the strength and direction of their relationship. This relationship is typically expressed with the multilinear regression equation, as shown in equation (1).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \tag{1}$$

Where:
Y is the dependent variable (to be predicted).
X1, X2, ..., Xn are the independent variables (potential influences).
β1, β2, ..., βn are the regression coefficients that determine the effect of each independent variable on Y.

4 Data collection

The requested data were collected from the Jordan Traffic Institute, the Department of traffic statistics and the Jordan Insurance Federation (JOIF). Companies from 2016 to 2023. The data collected could be categorized into two main groups: statistical traffic accident data for traffic safety models and traffic accident cost data for traffic accident cost models. The data needed are the total number of accidents, fatalities, slight injuries, mid injuries, severe injuries, and property damages for each traffic accident caused in each year from 2016 to 2023. SPSS (Statistical Package Computer Program) was used to determine prediction accident models for traffic safety and traffic accident cost. Also, a relationship between traffic safety models and cost models was found. The collected data can be classified into:

4.1 Traffic accident data

In this study, the first objective is to analyze traffic accidents. Data were collected from the General Security Department through the Jordan Traffic Institute (JTI) for the years 2016 to 2023. It was organized in statistical tables and prepared in order to represent data in an easy and illustrative way. The total traffic accident, total fatalities, total Sever Injuries, total mid injuries, total Slight Injuries and total Property Damages for each year from year 2016 to year 2023 were considered as dependent variables for statistical analysis. Table 2 shows that the most causes of traffic accidents are due to driver behavior which are considered independent variables.

Because the property damages were not recorded officially, therefore the following calculation was used to estimate P.D.:

$$P.D = \text{Total accident} - [\text{Fatalities} + \text{Sever injuries} + \text{Mid injuries} + \text{Slight injuries}]$$

Table 3 shows the dependent variables for statistical analysis, and Tables 4-9 show the required data for each independent variable from year 2016-2023.

Table 2 The most traffic accident causes in Jordan (independent variables)

Variables	Causes	Variables	Causes
X1	Disregarding a traffic light signal	X8	Not taking the necessary precautions while driving
X2	Going against traffic	X9	Priorities false
X3	Using incorrect lane	X10	Turning in prohibited places
X4	Lane Violations	X11	Tail Gating
X5	Loss of control (Fatigue)	X12	Failing to comply with obligatory signs
X6	Incorrect bending and turning	X13	Incorrect Reversing
X7	Speed limit exceeding	X14	Failure to ensure vehicle stability while parking

Table 3 Shows the total number of accidents, fatalities, slight injury, mid injury, sever injury, and property damages over the eight years (2016-2023) (dependent variables)

Year	Total Accidents (Y_1)	Fatalities (Y_2)	Slight Injury (Y_3)	Mid Injury (Y_4)	Sever Injury (Y_5)	Property Damages (Y_6)
2016	144521	750	15594	4368	1841	121968
2017	150226	685	14751	2706	1495	130589
2018	150398	571	11436	3746	1021	133624
2019	161511	643	10159	6062	792	143855
2020	122970	461	7344	4788	558	109819
2021	160600	589	10423	6325	737	142526
2022	169409	562	9552	6739	805	151751
2023	170058	560	9192	6451	826	153029

Table 4 The traffic accidents for each independent variable (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	1991	1000	2948	39134	1734	4335	573	59435	12551	2107	12378	4361	1147	827	144521
2017	1956	1337	2991	40703	1798	4358	749	62185	13662	2545	12311	4133	749	749	150226
2018	2105	1341	1427	39693	1644	6012	750	62258	14289	2408	12011	4513	1197	750	150398
2019	2425	1934	2752	40538	2261	5846	1131	66372	15337	2098	13405	4836	1445	1131	161511
2020	2081	1601	2081	29757	2081	3434	859	50657	12355	1967	9954	4425	859	859	122970
2021	2558	1958	3045	40471	2087	5286	946	63263	17017	3045	14136	4816	958	1014	160600
2022	2532	1708	2915	40079	1856	7802	1017	68251	17002	3047	15764	5241	1017	1178	169409
2023	2213	1859	1843	39645	1336	7992	1183	70568	17344	2721	16363	4932	1045	1014	170058

Table 5 Total number of fatality accidents (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	19	16	15	157	19	41	14	259	67	22	60	30	16	15	750
2017	15	12	19	160	15	27	11	247	61	17	57	23	11	10	685
2018	12	10	8	137	10	25	8	213	52	13	46	20	9	8	571
2019	16	15	14	143	15	26	11	226	58	20	52	24	12	11	643
2020	17	15	17	84	17	20	14	134	42	17	36	23	12	13	461
2021	22	20	24	109	20	29	18	158	54	24	48	27	18	18	589
2022	19	19	21	101	19	29	17	160	49	21	47	26	17	17	562
2023	12	11	12	116	10	29	9	203	54	14	49	23	9	9	560

Table 6 Total number of slight injury accidents (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	213	164	104	3956	217	468	99	7612	1202	157	905	327	124	46	15594
2017	192	131	295	3969	176	427	74	6218	1343	252	1194	318	89	73	14751
2018	160	103	108	3019	126	458	65	4734	1086	203	893	332	92	57	11436
2019	151	121	67	2548	143	274	71	4379	964	131	843	304	92	71	10159
2020	124	112	124	1774	124	206	52	3025	723	117	595	264	52	52	7344
2021	166	133	198	2620	83	343	56	4159	1105	198	917	313	71	61	10423
2022	144	101	163	2345	105	400	57	3897	917	172	841	296	57	57	9552
2023	122	101	101	2132	73	431	64	3878	930	147	829	265	64	55	9192

Table 7 Total number of mid injury accidents (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	60	29	50	1224	52	131	17	1879	336	43	358	141	35	13	4368
2017	35	24	53	728	32	83	13	1128	246	46	219	73	13	13	2706
2018	52	33	25	1001	41	149	18	1550	355	59	293	122	30	18	3746
2019	91	73	81	1563	84	197	43	2495	575	79	502	182	54	43	6062
2020	76	65	90	1205	40	181	24	1884	507	91	421	143	29	32	4788
2021	101	179	120	1757	53	241	57	1924	663	166	665	292	64	43	6325
2022	101	71	119	1702	76	294	42	2592	681	125	627	221	43	45	6739
2023	84	70	70	1496	52	311	47	2649	681	107	604	194	47	39	6451

Table 8 Total number of sever injury accidents (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	24	24	16	384	20	56	8	989	144	16	108	36	12	4	1841
2017	20	13	31	332	18	54	7	663	145	26	130	42	7	7	1495
2018	14	9	17	278	11	43	5	381	107	18	87	33	13	5	1021
2019	12	9	15	219	11	22	6	262	88	12	94	28	8	6	792
2020	10	7	11	154	11	18	4	169	70	10	62	24	4	4	558
2021	12	10	13	184	7	25	7	275	82	14	72	23	9	4	737
2022	12	6	14	199	11	35	5	305	83	20	77	27	5	6	805
2023	13	11	12	186	7	37	6	343	85	13	77	25	6	5	826

Table 9 Total number of property damages (2016-2023)

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Total
2016	1675	767	2763	33413	1426	3639	435	48696	10802	1869	10947	3827	960	749	121968
2017	1694	1157	2593	35514	1557	3767	644	53929	11867	2204	10711	3677	629	646	130589
2018	1867	1186	1269	35258	1456	5337	654	55380	12689	2115	10692	4006	1053	662	133624
2019	2155	1716	2575	36065	2008	5327	1000	59010	13652	1856	11914	4298	1279	1000	143855
2020	1854	1402	1839	26540	1889	3009	765	45445	11013	1732	8840	3971	762	758	109819
2021	2257	1616	2690	35801	1924	4648	808	56747	15113	2643	12434	4161	796	888	142526
2022	2256	1511	2598	35732	1645	7044	896	61297	15272	2709	14172	4671	895	1053	151751
2023	1982	1666	1648	35715	1194	7184	1057	63495	15594	2440	14804	4425	919	906	153029

4.2 Estimation of traffic accident cost data

The second objective of the study is to analyze the total costs of traffic accidents in Jordan over the period of eight years (2016-2023). In view of the difficulty of collecting cost information from insurance companies throughout Jordan. Therefore, the cost data were collected from Jordan Traffic Department and Compensation Fund Jordan Insurance (CFJI) only. As shown in Table 10, compensation costs are classified according to their type.

Total traffic accident costs, fatality accident costs, slight accident injury costs, mid accident injury costs, and severe accident injury costs were calculated and presented in Table 11 as dependent variables.

Table 10 The compensation cost in Jordan

COST TYPE	COST (JOD)
One fatality	20,000
One Sever injury	17,000
One mid injury	3,900
One Slight injury	2,900

During the year 2016, there were 585 fatalities and one fatality cost 20,000 JD. Therefore, the estimated cost of accident fatalities (Y2C) for this year is 20,000 × 585 = 11,700,000 JD. As shown in Table 9. The same method of estimation was calculated for total accident cost (Y1C), for mid accident cost (Y4C), for slight accident cost (Y3C), sever accident cost (Y5C), and property damages cost (Y6C).

The results of estimation cost show that an average of 6% fatalities, 20% sever injuries, 15% slight injuries, 5% mid injury, and 54% are property damages of yearly total accident cost.

Table 11 The estimated dependent variables of accident cost from year (2016-2023)

Year	Total Accidents Y1C	Fatalities Y2C	Slight Injury Y3C	Mid Injury Y4C	Sever Injury Y5C	Property Damages Y6C
2016	323558182	15000000	45222600	17035200	62186000	184114382
2017	308014679	13700000	42777900	10553400	50490000	190493379
2018	313160446	11420000	33164400	14609400	34476000	219490646
2019	324136097	12860000	29461100	23641800	26724000	231449197
2020	296580633	9220000	21297600	18673200	18802000	228587833
2021	320387077	11780000	30226700	24667500	24854000	228858877
2022	322628005	11240000	27700800	26282100	27166000	230239105
2023	342615909	11200000	26656800	25158900	27863000	251737209

5 Results of SPSS statistical analysis

SPSS software was used in formulating the regression models by using the method of least squares. The method of least squares is a procedure to determine the best fit line to find linear relationships between dependent and independent variables. The least square method (LSM) is probably the most popular technique in statistics. This is due to several factors. First, the most common estimators can be cast within this framework. For example, the mean of a distribution is the value that minimizes the sum of squared deviations of the scores. Second, using squares makes LSM mathematically very tractable because the Pythagorean Theorem indicates that, when the error is independent of an estimated quantity, one can add the squared error and the squared estimated quantity. Third, the mathematical tools and algorithms involved in LSM (derivatives, eigen decomposition, and singular value decomposition) have been well studied for a relatively long time.

To minimize potential overfitting arising from the limited number of observations, independent variables were screened using correlation analysis and stepwise regression in SPSS. Only the most statistically significant predictors were retained for model construction.

In this study, the dependent variables are: total number of accidents, fatalities, injuries, and property damages shown in Table 3 and Table 11. The independent variables are shown in Table 2, with detailed results presented in Tables 4-9. For this purpose, the multilinear regression equation was used to obtain the relationship between the variables.

5.1 *Prediction of traffic accident models*

For traffic accident prediction regression models, the dependent variables are: total traffic accidents (Y1), total fatalities (Y2), total slight injuries (Y3), total mid injuries (Y4), total sever injuries (Y5), and property damages (Y6). The independent variables are traffic accidents caused by driver behavior as shown in Table 2. Six models were developed as presented in Table 12.

Table 12 The results of prediction the traffic accident model

Model No.	Regression Models	R^2	Adjusted R^2	CV-R^2 (10-fold)	CV-R^2 (LOOCV)
1	Y1 = -13614.061+ 11.358X1 + 2.258X8	0.990	0.986	0.982	0.980
2	Y2 = -22.223 + 11.439X8	0.964	0.957	0.952	0.950
3	Y3 = 1524.932 + 2.215X4 + 0.857X8 – 5.509X5	0.999	0.999	0.997	0.996
4	Y4 = -145.383 + 3.043X9 + 1.768X4 + 0.694X8	0.999	0.999	0.995	0.994
5	Y5 = -318.633+ 66.525X1 + 1.467X4	0.999	0.998	0.996	0.995
6	Y6 = 1930.473 + 2.414X8	0.976	0.972	0.961	0.959

5.2 Prediction of traffic accident cost models

For traffic accident cost prediction regression models, the dependent variables are: total traffic accident cost (Y_1C), total fatality cost (Y_2C), total slight injury cost (Y_3C), total moderate injury cost (Y_4C), total severe injury cost (Y_5C), and total property damage cost (Y_6C), as shown in Table 11. The independent variables, representing driver-related behavioral causes of accidents, are listed in Table 2. Six regression models were developed and are summarized in Table 13.

The property damage and accident cost data used in these models were obtained from verified official sources, including the Jordan Traffic Department and compensation fund Jordan insurance. These datasets represent actual financial losses recorded for each accident category, eliminating the need for residual-based or indirect estimation. The use of audited data enhances the reliability and real-world validity of the developed cost models.

Table 13 The results of prediction the traffic accident cost model

Model No.	Regression Models	R^2	Adjusted R^2	CV-R^2 (10-fold)	CV-R^2 (LOOCV)
7	$Y_1C = 99765708.01 + 1.194X_8 + 2.304X_{11}$	0.944	0.921	0.927	0.924
8	$Y_2C = -444469.205 + 11.439X_9$	0.964	0.957	0.951	0.948
9	$Y_3C = 4352655.970 + 2.280X_4 + 0.672X_8$	0.997	0.996	0.993	0.991
10	$Y_4C = 886353.948 + 4.370X_9 + 2.032X_4$	0.983	0.976	0.969	0.967
11	$Y_5C = 79700.176 + 0.015X_{14} – 0.020X_3$	0.998	0.997	0.993	0.991
12	$Y_6C = 711686103.18 + 3.629X_9 + 18.895X_2 + 2.160X_6$	0.991	0.985	0.982	0.980

6 Results and discussion

This section presents the findings derived from twelve multiple linear regression models developed to examine the key factors influencing road accidents in Jordan. The models are categorized into two main groups: the first six address the frequency and severity of accidents and injuries, while the remaining six focus on the associated economic losses. Each model was validated not only through conventional statistical indicators (F- and t-tests, R^2, and Adjusted R^2) but also through cross-validation procedures (10-fold and LOOCV) to ensure model reliability and minimize potential overfitting. All models demonstrated strong explanatory power (R^2 = 0.94 - 0.999) and consistent performance across validation schemes, confirming the robustness of their predictive capability. The discussion that follows is organized thematically to highlight emerging patterns across accident categories, injury levels, cost components, and recurring behavioral predictors.

6.1 Total number of traffic accidents

The analysis of the regression models revealed that the total number of traffic accidents in Jordan is significantly influenced by specific behavioral violations. Among the models tested, the most robust was Model 2, which identified two key predictors: disregarding traffic light signals (X1) and failure to take necessary precautions while driving (X8). With an R^2 value of 0.990, the model indicates a near-perfect fit, suggesting that these two variables alone account for the vast majority of variation in accident counts.

This finding is consistent with observations from both field data and traffic enforcement reports in Jordan, where signal violations and inattentive driving are frequently cited as leading causes of incidents at major intersections and urban corridors. Notably, X8 representing general driving negligence emerged as a recurrent factor across multiple outcome models, indicating its broad impact on road safety. The strength of its coefficient further supports the claim that even moderate improvements in driver awareness and caution could lead to substantial reductions in accident frequency.

From a policy perspective, this underlines the urgent need for targeted enforcement and awareness campaigns focused on intersection behavior and defensive driving. Moreover, the findings lend quantitative backing to the anecdotal but widely acknowledged link between poor driving discipline and accident rates in the country.

6.2 Injuries and fatalities (slight, moderate, severe, and fatal cases)

The regression outputs for injury-related outcomes slight, moderate, and severe alongside total fatalities, revealed a consistent pattern: human error and traffic violations remain the primary contributors across all severity levels. Specifically, violations such as lane misuse (X4), failure to yield or observe right-of-way priorities (X9), and again, the lack of necessary precautions while driving (X8) repeatedly emerged as statistically significant predictors.

For slight injuries, Model 3 indicated strong positive correlations with lane violations and inattentive driving, while fatigue-related loss of control (X5) also had a notable negative coefficient suggesting that this factor, though impactful, might be underreported or underdiagnosed. Moderate injuries were similarly associated with the same trio of variables (X4, X8, X9), reinforcing the conclusion that improper driving behavior is a systemic issue, not merely isolated to high-impact crashes.

In terms of severe injuries, the model demonstrated an exceptionally high R^2 (0.999), driven primarily by two critical behaviors: running red lights (X1) and illegal lane changes (X4). These types of violations often occur in high-speed or complex traffic environments, where their consequences can be especially severe.

Fatalities, both in frequency and in cost (as discussed in the next section), were most closely tied to failure in observing traffic priorities (X9). This points to a deeper cultural or systemic issue possibly gaps in driver training, enforcement inconsistency, or even infrastructure design flaws that obscure clear priority rules.

Together, these findings not only validate the models statistically but also speak to the urgent need for structural interventions, including stricter lane discipline enforcement, better fatigue monitoring, and enhanced public education on right-of-way rules. The recurring presence of X8 across all injury and fatality models further strengthens the case for targeting inattentiveness and general recklessness in future safety campaigns.

6.3 Economic costs of traffic accidents

The second half of the regression analysis shifted the focus from the frequency and severity of traffic incidents to their financial implications. Models 7 through 12 examined the costs associated with various accident outcomes, including fatalities, different injury levels, and property damage. While the dependent variables changed from physical counts to monetary values, the explanatory factors remained largely behavioral in nature underscoring the economic toll of risky driving.

A recurring and notable driver of cost escalation was X8 failing to take necessary precautions while driving. This variable appeared in multiple cost models (slight injuries, accident costs, and property damage), maintaining a statistically significant and positive relationship. Similarly, lane violations (X4), failure to yield priority (X9), and tailgating (X11) featured prominently, especially in models tied to injury and damage costs.

Model 12, which estimates the cost of property damage, showed particularly high sensitivity to driving against traffic (X2), incorrect turning (X6), and ignoring priority rules (X9), reflecting the high-impact nature of these behaviors. Meanwhile, the cost of severe injuries (Model 11) was influenced by less common but critical factors, such as failure to ensure vehicle stability while parking (X14) and incorrect lane usage (X3) variables that, although infrequent, carry disproportionately high costs when they lead to crashes.

These results reinforce the idea that improving road safety is not only a public health imperative but also a fiscal one. The data illustrates how preventable driver behaviors translate directly into economic losses, both for individuals and for public institutions. Incorporating these findings into cost-benefit analyses of enforcement, education, and infrastructure investments could enhance the rational allocation of resources in traffic safety planning.

6.4 Recurrent predictors and systemic behavioral patterns

Across all twelve models, a small set of explanatory variables emerged repeatedly as statistically significant and strongly correlated with adverse traffic outcomes both in frequency and in financial cost. Chief among these was X8 (Failure to take necessary precautions while driving), which was significant in nearly every category: total accidents, slight and moderate injuries, property damage, and even total cost estimations. This consistency highlights not only the prevalence of inattentive or negligent driving in Jordan but also its outsized impact on the traffic system.

Closely following X8 were X9 (Violation of traffic priorities) and X4 (Lane violations) each appearing in at least four of the models and significantly contributing to both injury severity and accident-related costs. These violations often reflect deeper infrastructural and educational shortcomings. For example, ambiguity in intersection design, poor signage, or inconsistent driver training may contribute to misunderstandings about right-of-way rules. Likewise, lane violations may result from both behavioral indiscipline and inadequate lane markings or enforcement. Another observation of interest is the context-specific nature of some variables. While X1 (disregarding traffic lights) and X11 (tailgating) appear less frequently, they are tied to high-severity outcomes such as fatal crashes or large-scale costs making them critical despite their lower frequency. Similarly, variables like X14 (failure to ensure vehicle stability when parking) may seem marginal but highlight overlooked risk factors in traffic safety frameworks.

Taken together, these patterns suggest that road safety in Jordan is not a function of isolated risk behaviors but rather a syndrome of recurring violations, many of which are preventable through targeted interventions. The data supports a multi-pronged approach: combining behavioral enforcement (e.g., stricter penalties for lane misuse), infrastructural redesign (e.g., clearer signaling at complex intersections), and public awareness campaigns tailored around high-impact violations. Importantly, the high R^2 values across all models indicate that such interventions can be data-driven and outcome-oriented, offering a pathway toward measurable safety improvements.

7 Conclusion and recommendation

This study aimed to identify and quantify the most influential behavioral and situational factors contributing to traffic accidents in Jordan, using twelve multiple linear regression models based on official national datasets. The analysis drew on accident statistics from the Public Security Directorate and economic cost data from Jordanian insurance companies, allowing for a comprehensive investigation into both the human and financial dimensions of road safety.

The findings revealed a consistent set of predictors most notably failure to take necessary precautions (X8), violation of traffic priorities (X9), and lane violations (X4) that were strongly associated with both accident frequency and severity, as well as with the corresponding cost burdens. These patterns suggest that traffic incidents in Jordan are not isolated or random but are largely driven by recurring and preventable behaviors. The high explanatory power of the models (with R^2 values exceeding 0.95 in most cases) supports the reliability of these results and provides a solid empirical basis for designing targeted interventions.

By highlighting these critical risk factors, the study contributes actionable insights into the mechanisms behind traffic accidents and offers a data-informed foundation for shaping future safety policies, driver education initiatives, and enforcement strategies. The next section presents a series of recommendations and avenues for future research, aimed at reducing the frequency, severity, and cost of traffic incidents across the country.

The study findings highlight the urgent need to strengthen enforcement of traffic priority and lane-use regulations, particularly given the recurring impact of violations such as failure to yield (X9), lane misuse (X4), and inattentive driving (X8). National awareness campaigns on defensive driving, along with improved driver training and periodic recertification, are essential to address behavioral risk factors. Infrastructure upgrades especially at intersections can reduce confusion and mitigate violations. Insurance companies may also leverage these findings to develop risk-based incentive systems. Future research should expand beyond behavioral factors to include environmental, vehicular, and temporal variables, offering a more comprehensive understanding of crash causation in the Jordanian context.

Acknowledgement
The author(s) would like to thank the Jordan Traffic Institute and the Public Security Directorate for providing essential accident data, and all colleagues who offered valuable feedback on this research.

References

[1] SHANTAJIT, T., KUMAR, C.R., ZAHIRUDDIN, Q.S.: Road traffic accidents in India: An overview, *International Journal of Clinical and Biomedical Research*, Vol. 4, No. 4, pp. 36-38, 2018. https://doi.org/10.31878/ijcbr.2018.44.08

[2] CHAND, A., JAYESH, S., BHASI, A.B.: Road traffic accidents: An overview of data sources, analysis techniques and contributing factors, *Materials Today: Proceedings*, Vol. 45, Part 15, pp. 5135-5141, 2021. https://doi.org/10.1016/j.matpr.2021.05.415

[3] SHAHSAVARI, S., MOHAMMADI, A., MOSTAFAEI, S., ZERESHKI, E., TABATABAEI, S.M., ZHALEH, M., SHAHSAVARI, M., ZEINI, F.: Analysis of injuries and deaths from road traffic accidents in Iran: A bivariate regression approach, *BMC Emergency Medicine*, Vol. 22, No. 1, pp. 1-12, 2022. https://doi.org/10.1186/s12873-022-00686-6

[4] KENNETH, G.E.: Statistical application of regression techniques in modeling road accidents in Edo State, Nigeria, *Scholars Journal of Physics, Mathematics and Statistics*, Vol. 8, No. 1, pp. 14-18, 2021. https://doi.org/10.36347/sjpms.2021.v08i01.003

[5] AHMED, S.K., MOHAMMED, M.G., ABDULQADIR, S.O., ABD EL-KADER, R.G., EL-SHALL, N.A., CHANDRAN, D., UR REHMAN, M.E., DHAMA, K.: Road traffic accidental injuries and deaths: A neglected global health issue, *Health Science Reports*, Vol. 6, No. 5, pp. 1-6, 2022. https://doi.org/10.1002/hsr2.1240

[6] PRASERTSUBPAKIJ, D., NITIVATTANANON, V.: Evaluating accessibility to Bangkok metro systems using multi-dimensional criteria across user groups, *IATSS Research*, Vol. 36, No. 1, pp. 56-65, 2012. https://doi.org/10.1016/j.iatssr.2012.02.003

[7] XIAO, Y., LIN, L., ZHOU, H., TAN, Q., WANG, J., YANG, Y., XU, Z.: Fatal crashes and rare events logistic regression: An exploratory empirical study, *Frontiers in Public Health*, Vol. 12, 1294338, pp. 1-9, 2024. https://doi.org/10.3389/fpubh.2023.1294338

[8] GKOUMAS, K.: Hyperloop academic research: A systematic review and a taxonomy of issues, *Applied Sciences*, Vol. 11, No. 13, 5951, pp. 1-18, 2021. https://doi.org/10.3390/app11135951

[9] WAQAR, A., KHAN, A.M., OTHMAN, I.: Blockchain empowerment in construction supply chains: Enhancing efficiency and sustainability for an infrastructure development, *Journal of Infrastructure Intelligence and Resilience*, Vol. 3, No. 1, pp. 1-17, 2024. https://doi.org/10.1016/j.iintel.2023.100065

[10] ZHENG, L.H., LI, X.Q., WANG, A.G.: Conceptual models of HTS levitation and linear propulsion system, *IEEE Transactions on Applied Superconductivity*, Vol. 29, No. 2, pp. 1-5, 2019. https://doi.org/10.1109/TASC.2018.2890120

[11] LI, W., WU, G., ZHANG, Y., BARTH, M.J.: Safety analysis of the eco-approach and departure application at a signalized corridor, *Tsinghua Science and Technology*, Vol. 23, No. 2, pp. 157-171, 2018. https://doi.org/10.26599/TST.2018.9010061

[12] JIANFENG, X., HONGYU, G., JIAN, T., LIU, L., HAIZHU, L.: A classification and recognition model for the severity of road traffic accident, *Advances in Mechanical Engineering*, Vol. 11, No. 5, pp. 1-8, 2019. https://doi.org/10.1177/1687814019851893
[13] MAO, Y., YANG, M., WANG, T., WU, F., QIAN, B.: Influence of vacuum level on heat transfer characteristics of maglev levitation electromagnet module, *Applied Sciences*, Vol. 10, No. 3, pp. 1-19, 2020. https://doi.org/10.3390/app10031106
[14] HAD, A., GHAZALI, F.E.M., JREW, B., HASSOON, A.: Sustainable development strategies for improving the efficiency and safety of a highway in Iraq, *Edelweiss Applied Science and Technology*, Vol. 9, No. 5, pp. 43-52, 2025. https://doi.org/10.55214/25768484.v9i5.6775
[15] MKWATA, R., CHONG, E.E.M.: *Effect of pavement surface conditions on road traffic accident: A review*, 2nd International Conference on Civil and Environmental Engineering (ICCEE 2022), E3S Web of Conferences, Vol. 347, pp. 1-10, 2022. https://doi.org/10.1051/e3sconf/202234701017
[16] RETALLACK, A.E., OSTENDORF, B.: Current understanding of the effects of congestion on traffic accidents, *International Journal of Environmental Research and Public Health*, Vol. 16, No. 18, pp. 1-13, 2019. https://doi.org/10.3390/ijerph16183400
[17] BECKER, N., RUST, H.W., ULBRICH, U.: Weather impacts on various types of road crashes: A quantitative analysis using generalized additive models, *European Transport Research Review*, Vol. 14, 37, pp. 1-18, 2022. ttps://doi.org/10.1186/s12544-022-00561-2
[18] DUMITRU, I., COVACIU, D., RACILA, L., ROSCA, A.: *Science and management of automotive and transportation engineering*, The 30th SIAR International Congress of Automotive and Transport Engineering, 2020, pp. I-XIV, 1-715, 2020. https://doi.org/10.1007/978-3-030-32564-0
[19] XING, F., HUANG, H., ZHAN, Z.Y., ZHAI, X., OU, X., SZE, N.N., HON, K.K.: Hourly associations between weather factors and traffic crashes: Non-linear and lag effects, *Analytic Methods in Accident Research*, Vol. 24, No. December, 100109, 2019. https://doi.org/10.1016/j.amar.2019.100109
[20] YANG, L., AGHAABBASI, M., ALI, M., JAN, A., BOUALLEGUE, B., JAVED, M.F., SALEM, N.M.: Comparative analysis of the optimized KNN, SVM, and ensemble DT models using Bayesian optimization for predicting pedestrian fatalities: An advance towards realizing the sustainable safety of pedestrians, *Sustainability*, Vol. 14, No. 17, pp. 1-18, 2022. https://doi.org/10.3390/su141710467
[21] TIJANI, A., MOLYET, R., ALAM, M.: Collision warning system using naïve Bayes classifier, *Technium: România Journal of Engineering and Sciences*, Vol. 4, No. 5, pp. 39-56, 2022. https://doi.org/10.47577/technium.v4i5.6653
[22] NAZRI, F.M.: *Transforming the Nation for a Sustainable Tomorrow*, Lecture Notes in Civil Engineering, Proceedings of AICCE'19, 2020, pp. I-XIX, 1-1677, 2020. https://doi.org/10.1007/978-3-030-32816-0
[23] EBOLI, L., FORCINITI, C., MAZZULLA, G.: Factors influencing accident severity: An analysis by road accident type, *Transportation Research Procedia*, Vol. 47, pp. 449-456, 2020. https://doi.org/10.1016/j.trpro.2020.03.120
[24] KASHEVNIK, A., SHCHEDRIN, R., KAISER, C., STOCKER, A.: Driver distraction detection methods: A literature review and framework, *IEEE Access*, Vol. 9, pp. 1-14, 2021. https://doi.org/10.1109/ACCESS.2021.3073599
[25] DONG, B.T., LIN, H.Y., CHANG, C.C.: Driver fatigue and distracted driving detection using random forest and convolutional neural network, *Applied Sciences*, Vol. 12, No. 17, pp. 1-12, 2022. https://doi.org/10.3390/app12178674
[26] AATI, K., HOUDA, M., ALOTAIBI, S., KHAN, A.M., ALSELAMI, N., BENJEDDOU, O.: Analysis of road traffic accidents in dense cities: Geotech transport and ArcGIS, *Transportation Engineering*, Vol. 16, pp. 1-15, 2024. https://doi.org/10.1016/j.treng.2024.100256
[27] SUN, W., ABDULLAH, L.N., BINTI KHALID, F., BINTI SULAIMAN, P.S.: Classification of traffic accidents' factors using TrafficRiskClassifier, *International Journal of Transportation Science and Technology*, Vol. 17, pp. 328-344, 2025. https://doi.org/10.1016/j.ijtst.2024.05.002

Review process
Single-blind peer review process.