

Evaluation of Safety Measures on the Highways of Isfahan Province Based on before-and-after Studies using the Experimental Bayes Method

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Abstract

Isfahan Province, Annually, experiences around 650 fatalities and 5,000 injuries due to traffic accidents, with a troubling 20% increase in these figures each year. Alarmingly, half of the traffic-related deaths occur during transport or while receiving medical care. The escalating number of vehicles, coupled with the rapid expansion of transport networks, has led to a significant rise in the frequency and severity of traffic accidents globally, a challenge particularly pronounced in Iran. This phenomenon has resulted in increasing human and economic losses. In light of these circumstances, the effectiveness of safety policies and preventive measures in Isfahan necessitates the implementation of scientific methods to evaluate interventions aimed at rectifying accident-prone areas, in accordance with international road safety standards. This study endeavors to compare various before-and-after evaluation methodologies. Utilizing the experimental Bayes method, it assesses safety measures implemented at 15 high-accident sites as part of the Safety Improvement Plan for Isfahan Province (e.g. widening the speed limit lane before the round place, installing detector for indicating safety signs, pavement rehabilitation of the speed lane, blocking inappropriate exits and creating parking lots, etc.). The analysis, grounded in experimental observations, aims to provide a robust foundation for future decision-making by transportation managers, planners and engineers. The findings from this assessment reveal that the interventions at the identified sites resulted in a notable 45% reduction in accidents, with a confidence level of 95%. This significant impact validates the appropriateness of the measures undertaken, highlighting their effectiveness in enhancing road safety in the province.

Keywords: Safety, Before-After Study, BAYES Method, Transport Networks

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1. Introduction

The escalating number of vehicles on the road, coupled with the rapid expansion of transport networks, has led to a significant rise in the frequency and severity of traffic accidents globally, a challenge particularly pronounced in Iran. This phenomenon has resulted in increasing human and economic losses. While advancements in motor vehicle technology have facilitated transportation, in particular in urban areas, these developments have also been accompanied by substantial financial and human costs. Recent statistics illustrate that road accidents have not only contributed to a rise in fatalities and economic injuries but have also led to numerous physical, mental and psychological disabilities. The adverse consequences of these incidents underscore the detrimental effects of imbalanced transport technology development.

Isfahan Province, a pivotal region in Iran, is characterized by approximately 12,000 kilometers of roadways, 50% of which are rural. Annually, the province experiences around 650 fatalities and approximately 5,000 injuries due to traffic accidents, with a troubling 20% increase in these figures each year. Alarmingly, half of the traffic-related deaths occur during transport or while receiving medical care.

In light of these circumstances, the effectiveness of safety policies and preventive measures in Isfahan necessitates the implementation of scientific methods to evaluate interventions aimed at rectifying accident-prone areas, in accordance with international road safety standards. This study endeavors to compare various before-and-after evaluation methodologies. Utilizing the experimental Bayes method, it assesses safety measures implemented at 15 high-accident sites as part of the Safety Improvement Plan for Isfahan Province. The analysis, grounded in experimental observations, aims to provide a robust foundation for future decision-making by

transportation managers, planners and engineers.

2. Literature Review

The modeling of accident frequency prediction has been extensively explored in the literature, with numerous studies contributing to the development of various analytical frameworks. [Mohammad Nour Al-Marafi et al. 2024] examined various methods for identifying hazardous locations and showed the Empirical Bayes method remains a cornerstone in evaluating the effectiveness of safety interventions and found that this approach outperformed others in accurately pinpointing high-risk sites. The study highlighted the method's robustness in accounting for regression-to-the-mean effects and its adaptability to different traffic conditions, reinforcing its applicability in contemporary traffic safety analysis.

A study by [Yu Song et al, 2018] assessed the impact of Transit Signal Priority (TSP) systems on traffic safety using an Empirical Bayes before-and-after study design in King County, Washington. The results indicated that TSP implementation led to a statistically significant reduction in total crashes, particularly rear-end and angle collisions, without adversely affecting pedestrian and bicyclist safety. These results underscore the potential of TSP as a viable safety enhancement measure in urban traffic management.

Road traffic injuries (RTIs) as the one of the major health problems in developed and developing countries particularly in Iran, are the first leading cause of years of life lost (YLL). [Maziyar Mollaei Pardeh, et al, 2024] studied on the 11-year trend of RTI-related mortalities in Iran. All-cause deaths as well as RTI-related mortalities' data were collected from the Civil Registration Organization (CRO) and Legal medical organization (LMO) of Isfahan during 2011-2021. The mid-year population, number of deaths due to RTIs, the crude and age-standardized mortality (per 100,000) of RTIs,

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and the percentage of proportional mortality by sex and year of accident during the study period were calculated and reported. Also, trend analysis was done using join point regression program.

During the study period, 11,248 deaths occurred due to RTIs in Isfahan province. 8,894 cases were male (79.03%), the highest number of deaths in both male and female cases was reported in those aged 15-39 years. Among the males, trend of standardized mortality in 2011-2015 was decreasing (annual percentage changes = -6.76(CI 95%: -2.53, -15.03)), while in 2015-2021 it was increasing (annual percentage changes = 3.00 (CI 95%: 0.63, 9.87)). However, no significant trend was observed among females.

The results of this study showed that the number and standardized mortality rate of RTIs decreased during the 11-year period. It seems that applying stricter policies, improving the quality of the roads of the province, improving the quality of cars, and increasing the number of hospital and pre-hospital medical facilities can play an effective role in reducing RTIs.

Notable among these is [Shankar et al, 1999] investigation, which examined both Poisson and negative binomial models for estimating accident occurrences. [Al-Janahi 2003] utilized the Poisson model to analyze the relationship between traffic flow speed and accident rates under free-flow conditions, demonstrating that the proportion of heavy vehicles within traffic flow inversely correlates with accident frequency.

The implementation of safety measures is critical for mitigating accidents at diverse locations. Haer was the first to apply Bayesian methods to assess the impact of safety interventions on accident reduction. Subsequent research by Prasad, Council, and Lord in 1987, 1997, and 2001 has further explored the influence of safety measures on vehicular accidents. For instance, [Lord et al, 2001] employed the experimental Bayes method to evaluate accident changes before and after

converting 23 signalized and un-signalized intersections into roundabouts. Additionally, [Prasad, 1997] analyzed the safety implications of converting signalized intersections to stop signs, while [Haer, 1987] investigated the installation of barriers at 934 intersections equipped with flashing lights and 1,037 intersections with stop signs, also using the experimental Bayes method.

Further contributions include a study by [Griffith et al, 2007], which assessed the number and severity of accidents resulting from the implementation of raised shoulder lines on 182.6 kilometers of two-lane roads in Minnesota, utilizing the experimental Bayes method. [Sheikh-ul-Islami et al, 2009] conducted a series of before-and-after studies for safety analysis in, employing the same experimental Bayes methodology.

From 2016 to 2019, significant efforts were made to evaluate measures aimed at reducing accidents at both signalized and non-signalized intersections, as well as in construction zones. Noteworthy studies during this period include those by [Seyyed Keyvan Aghabek Egli et al, 2016], who reviewed safety measures for reducing accidents at non-signalized intersections, and [Seyyed Keyvan Aghabek Egli et al, 2017], who assessed safety measures for construction zones. Additionally, [Seyyed Keyvan Aghabek Egli et al, 2019] examined safety measures to mitigate speed-related accidents, along with various studies focusing on heavy vehicle accidents, pedestrian and cyclist safety, and issues related to young drivers and motorcyclists.

In the realm of intelligent transportation systems, research by [Amiri Ebrahim et al, 2017], has explored the effects of speed cameras on reducing speed violations, employing Bayesian methods and comparative group analyses on the Qazvin-Rasht and Bam-Kerman corridors.

A review of methods for assessing the effectiveness of interventions in accident-prone areas highlights a significant limitation of

traditional before-and-after studies: the lack of comprehensive coverage of trends across the entire network. This gap can be addressed through the use of control samples, as discussed by [Esmaeil Ayati et al, 2006].

Finally, a case study examining the simultaneous implementation of corrective measures in accident-prone areas along the Malayer-Jokar axis, analyzed using the experimental Bayes method, found that the measures led to a 4% reduction in accidents over a 19-month period before and after implementation, as reported by [Mohammad Koochi et al, 2007].

3. Research Scope and Data

According to data from the [Road Maintenance and Transportation Organization, 2018-2022(correspondent 1399 – 1403 Solar Hijri)] and the Traffic Police of Isfahan Province, this region is one of the most significant provinces in Iran, comprising approximately 12,000 kilometers of roadways, of which 50% are classified as rural. Annually, the province experiences around 650 fatalities and approximately 5,000 injuries resulting from traffic accidents, with an alarming growth rate of 20% per year. Notably, half of these fatalities occur during transport or while receiving medical care.

In terms of safety metrics, bus traffic is eight times safer than pedestrian traffic and 2.5 times safer than truck traffic. Furthermore, the frequency of injury and fatal accidents tends to peak on weekends, with the highest incidence occurring between 4:00 PM and 9:00 PM on both weekdays and weekends. The average of casualty's number per fatal accident is 0.83 and per injury accident is 1.33; significantly, in 60% of serious injury cases, buses or trucks are involved.

In the context of extra-urban fatalities, Isfahan ranks third nationally, while it ranks twentieth in terms of fatalities per unit road length, reporting 12 deaths per 100 kilometers of arterial road. Approximately 50% of fatal

accidents occur in four counties: Isfahan, Kashan, Shahinshahr, and Nayin. Furthermore, 80% of fatal accidents are concentrated along 20% of the length of extra-urban roads. The probability of a fatal accident on Isfahan's roads is estimated at 1 in 100 million per kilometer.

A total of 118 accident hotspots have been identified within the province, with 50% of these locations fully addressed. Additionally, 25 new accident hotspots were recognized in 1401, all of which are currently under evaluation for resolution. Notably, the frequency of accidents involving three or more fatalities and three or more injuries in the "Kashan-Isfahan" traffic police jurisdiction exceeds expectations when compared to other areas.

Specific routes, such as the Isfahan-Kashan-Qom freeway from Sarasiab to Khorramdasht, have been identified as particularly hazardous for both passenger and cargo transport. The Isfahan-Baharestan corridor, particularly the area from the Isfahan Customs Office to the centralized parking lot, reports a high incidence of accidents involving pedestrians, motorcyclists, and light trucks. Additionally, the primary and secondary routes branching from the Dashti axis exhibit a significant density of motorcycle-related accidents. Areas surrounding Shahreza, including the region between Manzariyeh village and the Shahreza ring road, as well as other specified locations, demonstrate a high concentration of pickup truck accidents.

Research conducted in Isfahan province regarding the tripartite contributions to accidents indicates that the human factor is responsible for approximately 90% of cases. Consequently, revising the licensing process, enhancing required training, amending the extension procedures, addressing violations more stringently, and increasing penalties for infractions may serve as viable solutions. It is noteworthy that 50% of accidents occur at intersections on suburban roads.

The leading causes of death among victims of traffic accidents are multiple fractures (32%)

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and head injuries (30%). These injuries often result from the failure to use seat belts, vehicle overloading, and the presence of unsecured objects within vehicles, all of which highlight deficiencies in user education and enforcement of regulations. In 90% of fatal and injury-related accidents, the deceased or injured individuals did not utilize seat belts, indicating a significant gap in road user education and law enforcement. The usage rate of rear seat belts is below 5%. Furthermore, 40% of fatalities arise from vehicle rollovers, while 44% are attributed to

collisions with other vehicles. Analysis reveals that 41% of fatal accidents result from inattention, 18% from driver fatigue or drowsiness, 12% from improper lane changes, and 5% from speeding. Approximately 5% of vehicles fail to meet the minimum speed requirements on freeways, while nearly 4% engage in unauthorized overtaking maneuvers. Alarmingly, over 50% of drivers admit to using their cell phones while driving, and only 16% of motorcyclists wear helmets, with a mere 2% of pedestrians doing the same.

Table 1. Characteristics of the Studied Sites on Provincial Transportation Routes Subject to Safety Interventions

Sec. No	High Crash No	Route Name	Route Type	RouteName	Geometry Description	Length (M)
1	ISF017	Shahreza- Isfahan	Highway	Eftekharieh	Arch	800
2	ISF027	Zarinshahr- Isfahan	Highway	Zob Ahan Gardne	Intersection-Arch	800
3	ISF041	Tiran-Najafabad	Highway	Nehzat Abad	Bridge	800
4	ISF042	Isfahan-Nayin	Highway	Tara Bar	Intersection	800
5	ISF043	Hana-Kameh	Secondary Road	Arzhnak Gardne	Arch	800
6	ISF045	Isfahan-Nayin	Highway	Koshkouieh	Bridge-Arch	800
7	ISF046	Daran-Aligodarz	National Main	Qafar	Intersection-Arch	800
8	ISF047	Daran-Aligodarz	National Main	Aznuleh	Intersection	800
9	ISF048	Isfahan-Tehran	Highway	Three-way intersection	Intersection	800
10	ISF049	Shahrza- Isfahan	Highway	Gas station and Sepehrabad	Intersection	800
11	ISF050	Isfahan-Tehran	Highway	Pegah	Bridge-Arch	800
12	ISF051	Varnamkhast-Sefidasht	National Main	Railway bridge	Intersection	800
13	ISF058	Isfahan-Nayin	Highway	Sajzi entrance	Bridge-Arch	800
14	ISF062	Isfahan-Zobahan Free way	Free way	River bridge	Intersection	800
15	ISF067	Kashan-Qom Free way	Free way	Abshirin	Bridge	800

Table 2. The Implementation of Safety Measures Type

Sec. No	High Crash No	Route Name	Implemented Safety Measures type
1	ISF017	Shahreza- Isfahan	installing fluorescent directional signs, transverse rumble, removing some of the trench and installing detector for indetecting safety signs
2	ISF027	Zarinsahr- Isfahan	installing appropriate overhead route guidance signs before the exit, modifying and completing route guidance signs on the outward axis, and creating a transverse rumble to control speed before the exit, as well as blocking access from Zob Ahan Highway to the western bypass way of Isfahan on the return route according to the safety plan.
3	ISF041	Tiran-Najafabad	Rehabilitation of the asphalt pavement of the speed lane and detecting the round place according to the proposed safety plan
4	ISF042	Isfahan-Nayin	Widening the speed limit lane before the round place and installing signs to provide visibility, advance warning, and appropriate route guidance before the round place
5	ISF043	Hana-Kameh	Pavement and curve correction, removing some of the trench to increase visibility zone, installing signs to provide visibility, longitudinal and latitudinal rumble painting longitudinal yellow line, as well as replacing existing directional signs with fluorescent directional signs.
6	ISF045	Isfahan-Nayin	Blocking access to the underpass, removing some of the trench, latitudinal rumble, speed limit indicator sign, and horizontal curve 100 meters from the curve, creating an escape route for heavy vehicles
7	ISF046	Daran-Aligodarz	Creating a suitable transition zone
8	ISF047	Daran-Aligodarz	Extension of newjersey according to plan, canalization of the entrance and exit of the village and installation of appropriate route guidance signs
9	ISF048	Isfahan-Tehran	Modifying the access turning radius and creating an island to channelize access according to the safety plan.
10	ISF049	Shahrza- Isfahan	Blockage of the cut and flow transfer to the unlevel round under construction via the low speed line
11	ISF050	Isfahan-Tehran	Creating a low speed line to manage multiple accesses according to the safety plan
12	ISF051	Varnamkhast-Sefidasht	Bridge detection and painting longitudinal yellow lines and longitudinal rumble and installation of studs to separate the going and return routes, as well as installation of warning and enforcement detection signs for transverse rumble.
13	ISF058	Isfahan-Nayin	Blocking the cut and modifying the geometry of the entrance to the enclosure according to the safety plan
14	ISF062	Isfahan-Zobahan Free way	Installation of narrowing road signs and lane reduction warnings, installation of studs in the lane reduction area, latitudinal rumble and speed limit signs
15	ISF067	Kashan-Qom Free way	Blocking inappropriate exits and creating parking lots (rest areas) adjacent to the route

Table 3. Average Daily Traffic (ADT) before and after safety measures, Observed Accident Data Four Years Prior and Two Years Following the Implementation of Safety Measures

Sec. No	High Crash No	Route Name	adt-before	adt-after	Observed-before-Y\1	Observed-before-Y2	Observed-before-Y3	Observed-before-Y4	Observed-before-total	Observed-after-Y1	Observed-after-Y2	Observed-after-total
1	ISF017	Shahreza- Isfahan	12459	17793	2	1	0	1	4	1	1	2
2	ISF027	Zarinsahr- Isfahan	20638	31025	3	2	1	1	7	2	0	2
3	ISF041	Tiran-Najafabad	15952	23075	1	0	2	1	4	0	0	0
4	ISF042	Isfahan-Nayin	5690	7470	0	1	1	0	2	0	1	1
5	ISF043	Hana-Kameh	3328	6314	2	1	1	0	4	2	0	2
6	ISF045	Isfahan-Nayin	5690	7470	4	3	6	4	17	3	3	6
7	ISF046	Daran-Aligodarz	3227	6305	1	0	3	1	5	2	3	5
8	ISF047	Daran-Aligodarz	3227	4735	5	6	2	3	16	3	0	3
9	ISF048	Isfahan-Tehran	11401	13293	2	1	0	2	5	1	0	1
10	ISF049	Shahrza- Isfahan	14323	17793	6	5	2	2	15	5	2	7
11	ISF050	Isfahan-Tehran	9680	15783	4	3	1	1	9	2	0	2
12	ISF051	Varnamkhast-Sefidasht	2093	4066	3	2	1	2	8	3	3	6
13	ISF058	Isfahan-Nayin	6854	9596	5	3	2	1	11	3	0	3
14	ISF062	Isfahan-Zobahan Free way	29893	54001	6	3	1	4	14	1	2	3
15	ISF067	Kashan-Qom Free way	1648	1913	4	2	2	3	11	2	3	5

4. Research Method

The Experimental Bayes method serves as a statistical approach to estimate the long-term annual number of accidents at a site by utilizing a weighted average of short-term accident data. By incorporating the Experimental Bayes

method in before-and-after studies, the influence of regression to the mean is significantly mitigated. This study analyzes accident data collected from 15 sites along the transportation axes of Isfahan Province, focusing on a four-year period preceding and a two-year period following the implementation

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of safety measures, as outlined in the table above. The evaluation process employs the Experimental Bayes method within a Python environment, structured as follows:

A. Estimation of Expected Accident Frequency Prior to Intervention

1. Calculate the predicted accident frequency for each site on an annual basis before the intervention.
2. Compute weight corrections and aggregate the total predicted accidents for each site prior to the intervention.

B. Estimation of Expected Accident Frequency Following Intervention

3. Determine the predicted accident frequency for each site on an annual basis after the intervention.
4. Calculate correction factors to account for differences between pre- and post-intervention data.
5. Estimate the total expected accidents for each site following the intervention, assuming no measures had been implemented.

C. Assessment of the Effectiveness of Safety Measures

6. Estimate safety effectiveness as a likelihood ratio for each site.
7. Calculate safety effectiveness as a percentage change in accidents for each site.
8. Aggregate the safety effectiveness as a likelihood ratio across all sites.
9. Adjust for an unbiased estimate of safety effectiveness as a likelihood ratio.
10. Determine the unbiased estimate of safety effectiveness as a percentage change in accidents for all sites.

D. Estimation of Calculation Accuracy

11. Calculate the variance of the error-free estimate of safety performance as a likelihood ratio.
12. Compute the standard error for the likelihood ratio derived from Step 11.
13. Calculate the standard error of the error-free estimate of safety performance from Step 10.

14. Assess the reliability of the estimated safety performance using appropriate statistical methods.

The expected number of accidents at traffic police stations will be compared to other traffic police jurisdictions.

Specific areas of concern include the Isfahan-Kashan-Qom freeway axis, particularly from Sarasiab to Khorramdasht, which has been identified as hazardous for both passenger and cargo transport. Similarly, the Isfahan-Baharestan corridor, extending from the Isfahan Customs Office to the centralized parking lot, reports a high incidence of accidents involving pedestrians, motorcyclists, and light trucks. The main and secondary axes branching from the Dashti axis exhibit a notable density of motorcycle accidents. Areas surrounding Shahreza, including the region between Manzariyeh village and the Shahreza ring road, as well as other specified locations, demonstrate high concentrations of pickup truck accidents. Base on Legal medical organization (LMO) data and the research conducted in Isfahan province regarding the tripartite contributions to accidents indicates that the human factor is responsible for approximately 90% of cases. Thus, revising licensing procedures, enhancing required training, amending extension methods, addressing violations, and increasing penalties may provide viable solutions. Notably, 50% of accidents in the province occur at intersections on suburban roads.

The primary causes of death among victims of traffic accidents include multiple fractures (32%) and head injuries (30%). These injuries often stem from the failure to use seat belts, vehicle overloading, and the presence of unsecured objects in vehicles, reflecting deficiencies in user education and law enforcement. In 90% of fatal and injury-related accidents, the deceased or injured individuals did not utilize seat belts, highlighting significant gaps in road user education and enforcement. The usage rate of rear seat belts is below 5%.

Moreover, 40% of fatalities result from vehicle rollovers, while 44% stem from collisions with other vehicles. Analysis indicates that in 41% of fatal accidents, the cause is attributed to inattention, 18% to driver fatigue or drowsiness, 12% to improper lane changes, and 5% to speeding. Approximately 5% of vehicles do not

comply with minimum speed requirements on freeways, while nearly 4% engage in unauthorized overtaking maneuvers. Alarming, over 50% of drivers admit to using their cell phones while driving, and only 16% of motorcyclists wear helmets, with a mere 2% of pedestrians doing the same.

Table 4. Descriptive Statistics of Accident Frequency before and After the Implementation of Safety Measures in the Python Environment

	Observed-before-Y1	Observed-before-Y2	Observed-before-Y3	Observed-before-Y4	Observed-before-total	Observed-after-Y1	Observed-after-Y2	Observed-after-total
count	15/00	15/00	15/00	15/00	15/00	15/00	15/00	15/00
mean	3.2	2.2	1.7	1.7	8.8	2/00	1.2	3.2
std	1.86	1.7	1.44	1.28	4.94	1.3	1.32	2.11
min	0/00	0/00	0/00	0/00	2/00	0/00	0/00	0/00
25%	2/00	1/00	1/00	1/00	4.5	1/00	0/00	2/00
50%	3/00	2/00	1/00	1/00	8/00	2/00	1/00	3/00
75%	4.5	3/00	2/00	2.5	12.5	3/00	2.5	5/00
max	6/00	6/00	6/00	4/00	17/00	5/00	3/00	7/00

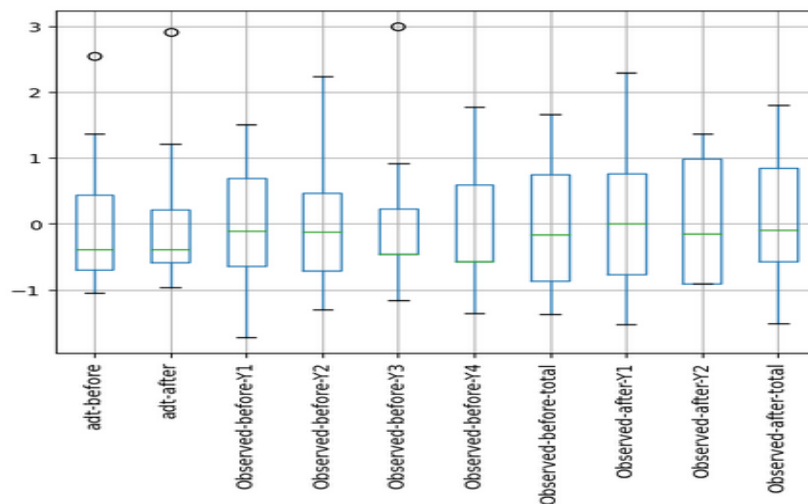


Figure 1. Descriptive Statistics of Accident in the Python

5. Statistical Principles Employed in the Study

Statistical Principles Employed in the Study

$$N_{SPF_{rs}} = AADT \times L \times 365 \times 10^{-6} \times e^{-0.312}$$

$N_{SPF_{rs}}$: Estimated Total Number of Accidents for the Baseline Condition of the Road Section
 $AADT$: Annual average daily traffic volume (number of vehicles per day)

L : Length of the road segment in meters

$$N_{Predicted} = N_{SPF_x} \times (AMF_{1x} \times AMF_{2x} \times \dots \times AMF_{xy}) \times C$$

$N_{Predicted}$: Number of accidents predicted prior to action

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AMF_{xy} : Accident correction factor for conditions xy

SPF: Safety Performance Functions

N_{SPF_x} : Estimate the average number of predicted accidents for the safety performance function x

OR_i : Estimating safety performance as Odds Ratio for each site

OR' : Odds Ratio for all site

$$r_i = \frac{\sum_{After\ Years} N_{Predicted\ A}}{\sum_{Before\ Years} N_{Predicted\ B}} = \frac{After\ 2\ years\ total}{Before\ 4\ years\ Total}$$

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$$N_{expected.A} = N_{expected.B} \times r_i$$

$$OR_i = \frac{N_{observed.A}}{N_{expected.A}}$$

$$AMF_i = 100 \times (1 - OR_i)$$

$$OR = \frac{OR'}{1 + \frac{Var(\sum_{All Sites} N_{expected.A})}{(\sum_{All Sites} N_{expected.A})^2}}$$

$$Var(\sum_{All Sites} N_{expected.A}) = \sum_{All Sites} [x(r_i)^2 \times N_{expected.B \times (1-w_{i.B})}]$$

$$OR' = \frac{\sum_{All Sites} N_{observed.A}}{\sum_{All Sites} N_{expected.A}}$$

$$SE(OR) = \sqrt{Var(OR)}$$

$$SE(AMF) = 100 \times SE(OR)$$

$$ABS(\frac{AMF}{SE(AMF)}) \geq 2$$

With a reliability of 95%, the action taken was effective.

Table 5. Before and After Predicted the Implementation of Safety Measures

Sec. No	High Crash No	Route Name	Predicted-before-Yr	Predicted-before-Yr	Predicted-before-Yr	Predicted-before-Yr	Predicted-before	Overdispersion Parameter K	Weighted Adjustment W	Expected AVG Crash Before	Predicted-After-Yr	Predicted-After-Yr	Predicted-After	Adjustment Factor R	Expected AVG crash FRQ After without treatment	Odds Ratio	Safety Effectiveness %	Risk Reduction (1-Wi.B)
1	ISF017	Shahreza-Isfahan	2.67	2.67	2.67	2.67	10.67	0.295	0.24	5.61	3.81	3.81	7.62	0.71	4.00	0.50	50.06	2.17
2	ISF027	Zarinshahr-Isfahan	4.42	4.42	4.42	4.42	17.68	0.295	0.16	8.72	6.65	6.65	13.29	0.75	6.55	0.31	69.48	4.13
3	ISF041	Tiran-Najafabad	3.42	3.42	3.42	3.42	13.67	0.295	0.20	5.92	4.94	4.94	9.88	0.72	4.28	0.00	100.00	2.48
4	ISF042	Isfahan-Nayin	1.22	1.22	1.22	1.22	4.87	0.295	0.41	3.18	1.60	1.60	3.20	0.66	2.09	0.48	52.08	0.81
5	ISF043	Hana-Kameh	0.71	0.71	0.71	0.71	0.71	0.295	0.83	1.28	1.35	1.35	2.70	3.79	4.87	0.41	58.95	3.21
6	ISF045	Isfahan-Nayin	1.22	1.22	1.22	1.22	4.87	0.295	0.41	12.03	1.60	1.60	3.20	0.66	7.89	0.76	24.00	3.06
7	ISF046	Daran-Aligodarz	0.69	0.69	0.69	0.69	2.76	0.295	0.55	3.77	1.35	1.35	2.70	0.98	3.68	1.36	-35.80	1.62
8	ISF047	Daran-Aligodarz	0.69	0.69	0.69	0.69	2.76	0.295	0.55	8.71	1.01	1.01	2.03	0.73	6.39	0.47	53.05	2.11
9	ISF048	Isfahan-Tehran	2.44	2.44	2.44	2.44	9.77	0.295	0.26	6.23	2.85	2.85	5.69	0.58	3.63	0.28	72.46	1.57
10	ISF049	Shahreza-Isfahan	3.07	3.07	3.07	3.07	12.27	0.295	0.22	14.41	3.81	3.81	7.62	0.62	8.95	0.78	21.79	4.36
11	ISF050	Isfahan-Tehran	2.07	2.07	2.07	2.07	8.29	0.295	0.29	8.79	3.38	3.38	6.76	0.82	7.17	0.28	72.11	4.15
12	ISF051	Vamankhast-Sefidasht	0.45	0.45	0.45	0.45	1.79	0.295	0.65	3.94	0.87	0.87	1.74	0.97	3.83	1.57	-56.76	1.29
13	ISF058	Isfahan-Nayin	1.47	1.47	1.47	1.47	5.87	0.295	0.37	9.12	2.06	2.06	4.11	0.70	6.39	0.47	53.03	2.83
14	ISF062	Isfahan-Zobahan Free way	6.40	6.40	6.40	6.40	25.61	0.295	0.12	15.36	11.57	11.57	23.13	0.90	13.87	0.22	78.37	11.06
15	ISF067	Kashan-Qom Free way	0.35	0.35	0.35	0.35	1.41	0.295	0.71	4.23	0.41	0.41	0.82	0.58	2.46	2.04	-103.60	0.42
Total			31.29	31.29	31.29	31.29	123.04			111.30	47.26	47.26	94.51		86.06			45.27

6. Conclusion

To facilitate the concurrent visualization of descriptive data across the study sites, a Geographic Information System (GIS) was employed. This approach utilized geographic location information of accident points collected by the traffic police in Isfahan Province. The input data encompassed average daily traffic volumes recorded before and after the implementation of safety measures, as well as the number of accidents occurring in the corresponding years.

Additionally, the model outputs, which included predicted accident frequencies both prior to and following the safety interventions, along with expected accident rates in the absence of such measures, were systematically displayed within the GIS environment. The resulting maps, presented below, provide a comprehensive spatial representation of the data, enhancing the understanding of the impact of safety actions on accident occurrences in the region.

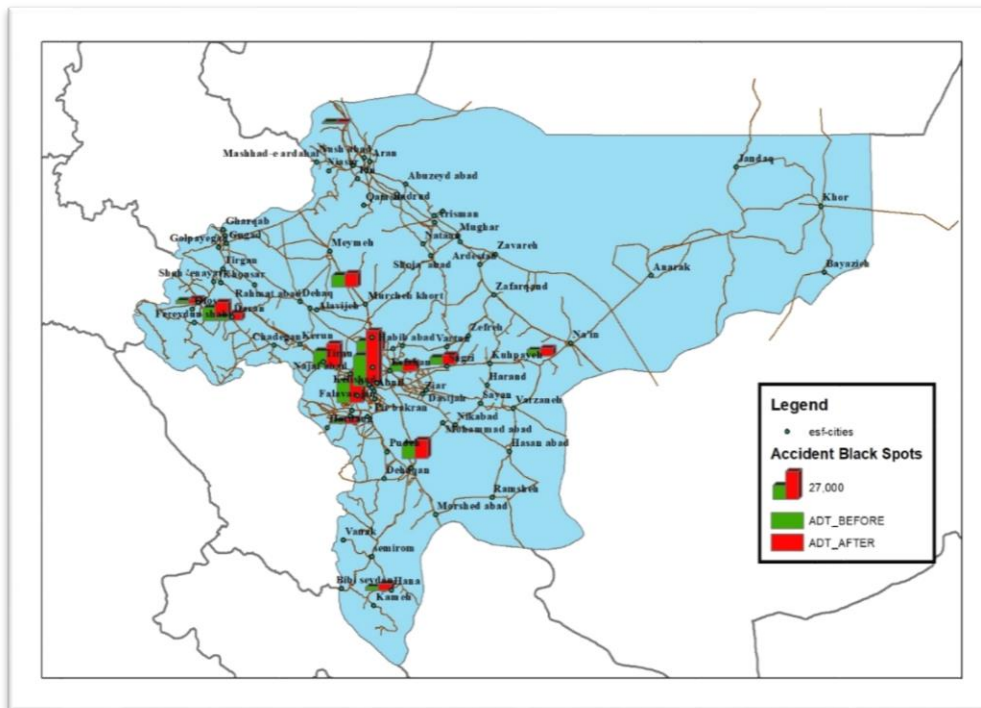


Figure 2. Average Daily Traffic (ADT) prior and after safety measures at the study sites

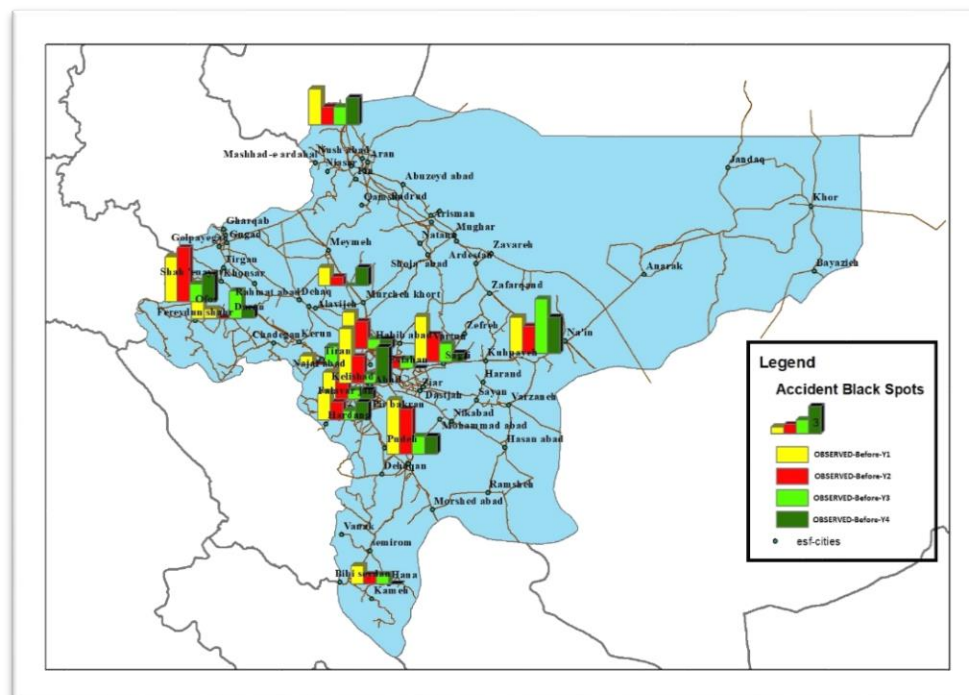


Figure 3. Number of accidents in the years prior safety measures were taken

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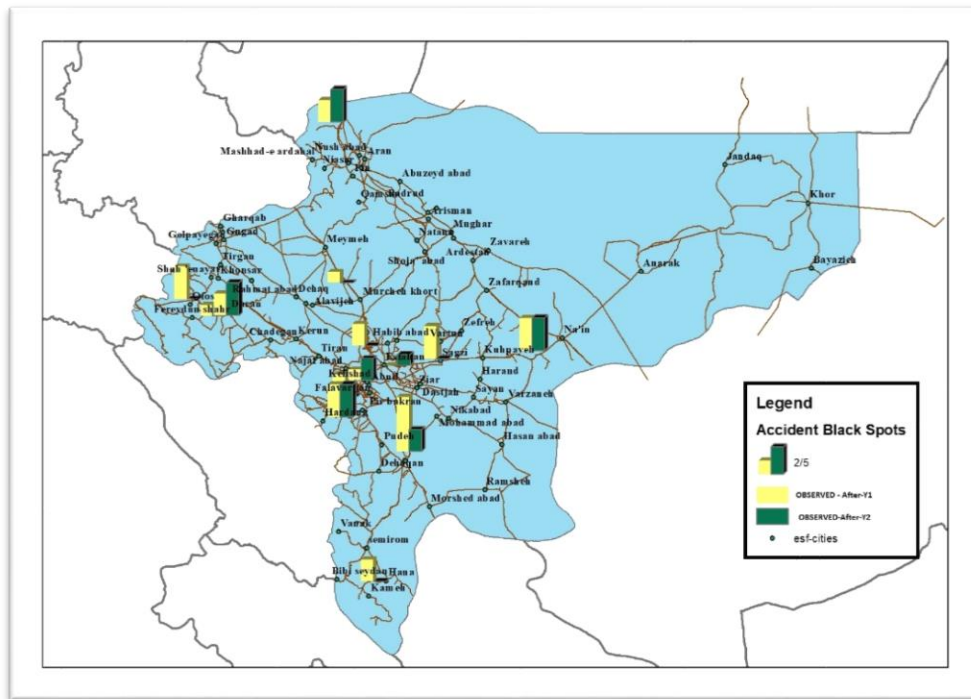


Figure 4. Number of accidents in the years following the implementation of the safety measure

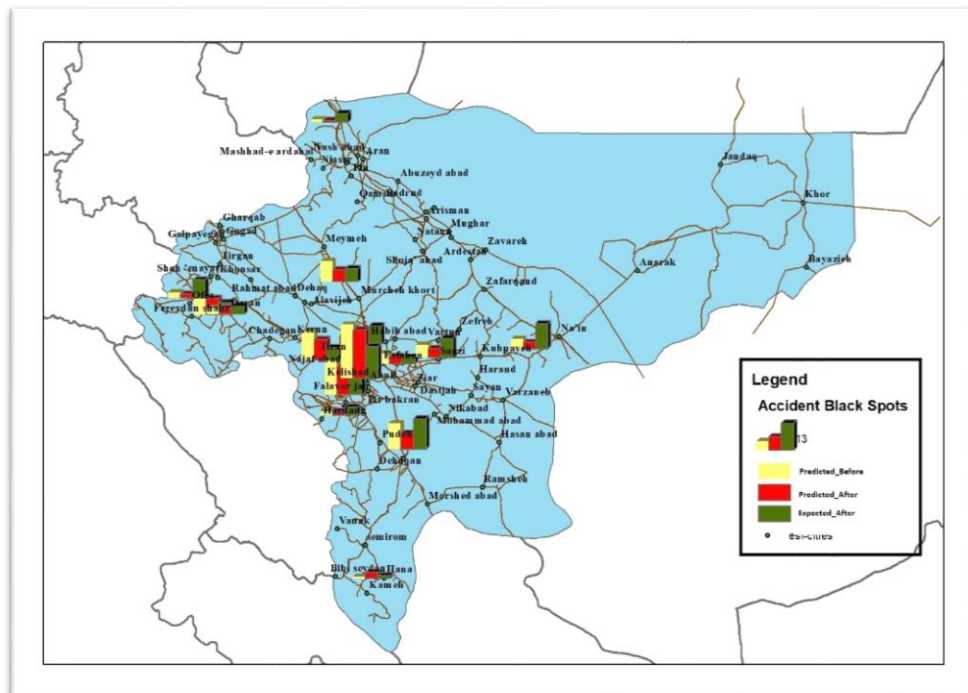


Figure 5. Predicted accidents prior and after and expected accidents, presuming neither safety action to be taken

The results of the evaluations conducted using the Experimental Bayes method on 15 accident-prone locations along the roads of Isfahan Province reveal a significant impact of the implemented safety measures. Based on

comparative observations before and after the intervention, the analysis indicates an approximate reduction in accident frequency of 45 percent, specifically quantified as 44.56 percent. This finding is supported by a

reliability level of 95%, underscoring the effectiveness of the measures taken in enhancing road safety in the region.

Table 6. Evaluation Results

Step 8: Aggregate the safety effectiveness as Odds Ratio across all sites.	OR	0.5578
This means that this measure will reduce accidents : $0.55 < 1$	OR'	0.5544
Step 10: Determine the unbiased estimate of safety effectiveness as a percentage change in accidents for all sites.		44.563
Step 11: Calculate the variance of the error-free estimate of safety performance as a likelihood ratio.		0.00833162
Step 12: Compute the standard error for the Odds Ratio derived from Step 11.		0.09127771
Step 13: Calculate the standard error of the error-free estimate of safety performance from Step 10.		9/12777117
Step 14: Assess the reliability of the estimated safety performance using appropriate statistical methods.		4.88212009
With a reliability of 95%, the action taken was effective.	4.88 > 2	
This action has reduced accidents by 44.56%.		
This result has a statistical confidence level of 95%.		

This study after comparing various before-and-after evaluation methodologies, shows that utilizing the experimental Bayes method, it assesses safety measures implemented at 15 high-accident sites as part of the Safety Improvement Plan for Isfahan Province (e.g. widening the speed limit lane before the round place, installing fluorescent directional signs, installing detector for indicating safety signs, rehabilitation of the asphalt pavement of the speed lane, blocking inappropriate exits and creating parking lots, etc.). The analysis, grounded in experimental observations, aims to provide a robust foundation for future decision-making by transportation managers, planners and engineers.

The findings from this assessment reveal that the interventions at the identified sites resulted in a notable 45% reduction in accidents, with a confidence level of 95%. This significant impact validates the appropriateness of the measures undertaken, highlighting their effectiveness in enhancing road safety in the province.

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