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Rising trend in traffic accident mortality in Iran after a decade of decline (2006–2022): time to raise the alarm

Mohammad Reza Taherian[1], Farzad Maleki[1], Marziye Talebi[1], Mehran Rostami Varnosfaderani[1], Seyed Davood Mirtorabi[2], Mehdi Forouzesh[2] and Seyed Saeed Hashemi Nazari[3,4*]

Abstract

Background This study examines epidemiology and trend of mortality rates due to traffic accidents in Iran from 2006 to 2022.

Methods Data were collected from the Iranian Legal Medicine Organization and the Statistical Center of Iran. Age-standardized mortality rates were calculated using direct standardization. A Latent Class Growth Mixture Model (LCGMM) was employed to evaluate trends and identify provinces with similar patterns.

Results From 2006 to 2022, Iran recorded 325,851 traffic accident deaths, with a median age of 34 years; 78.8% were male. Most deaths occurred on intercity roads (63.84%, $n=208{,}021$), followed by urban roads (27.73%, $n=90{,}365$) and rural roads (7.63%, $n=24{,}859$). Mortality rates declined significantly from 38.86 per 100,000 in 2006 to 19.85 in 2017 but increased to 23.00 per 100,000 in 2022, underscoring a concerning public health issue. A reverse J-shaped trend was identified nationally using LCGMM, showing an initial decline (intercept: 48.13, SE = 1.32; slope: -3.67, SE = 0.34) followed by a significant upward trend (quadratic term: 0.14, SE = 0.02, $p < 0.001$). The quadratic term's highly significant *p*-value highlights the importance of this non-linear pattern. At the provincial level, six distinct mortality trend classes were identified, highlighting significant regional variations. Most provinces exhibited a reverse J-shaped pattern, except Sistan and Baluchestan and Kohgiluyeh and Boyer-Ahmad, which showed U-shaped trends.

Conclusion After a decade of decline (2006–2017), Iran's traffic fatalities resurged post-2017, potentially linked to economic strain, aging vehicle fleets, and inconsistent enforcement of safety regulations. Targeted interventions — subsidies for safer vehicles, infrastructure upgrades, and regional policies— are urgently needed to reverse this trend and align with global road safety goals.

Keywords Traffic accidents, Mortality rate, Latent class growth mixture model, Trend analysis

*Correspondence:
Seyed Saeed Hashemi Nazari
saeedh_1999@yahoo.com
[1]Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Legal Medicine Research Center, Legal Medicine Organization, Tehran, Iran
[3]- Prevention of Cardiovascular Disease Research Center,Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[4]Safety Promotion and Injury Prevention Research Center, Department of Epidemiology, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Introduction

As outlined by the World Health Organization (WHO), a traffic accident is defined as any fatal or nonfatal incident involving at least one in-motion vehicle [1]. Deaths attributed to traffic accidents encompass those occurring either during the accident or within 30 days afterward, arising from injuries sustained due to the accident [2]. Annually, approximately 1.35 million individuals lose their lives in road accidents worldwide. That means nearly 3,700 people lose their lives every day in crashes involving cars, motorcycles, bicycles, buses, trucks, or pedestrians. Injuries resulting from road accidents are estimated to rank as the 8th primary cause of mortality and the 7th cause of Disability-Adjusted Life Years (DALY) on a global scale across all age groups. Moreover, traffic accidents stand as the foremost cause of death for individuals aged 5–29 years and the first cause of DALY among individuals aged 10–49 years. Remarkably, the number of fatalities in crashes exceeds those attributed to HIV/AIDS [3, 4].

Low- and Middle-Income Countries (LMICs) are significantly more susceptible to road traffic accidents, with a crash mortality rate exceeding three times that of high-income countries. Despite having about 60% of the world's vehicles, LMICs account for 92% of global road fatalities. The impact of these accidents extends beyond public health, affecting the economy. LMICs are expected to face losses of around $834 billion from 2015 to 2030 due to both fatal and nonfatal crash injuries. Furthermore, the economic consequences are highlighted by a 3% reduction in the gross domestic product (GDP) of most countries resulting from road traffic crashes [3, 5, 6].

Several studies indicate a rising trend in fatalities resulting from Road Traffic Accidents (RTAs) in Africa, Asia, and the Eastern Mediterranean region (EMRO), in recent years. The EMRO stands out with the second-highest rates of traffic-related deaths globally. Notably, within the EMRO, Iran exhibits the highest rate of RTAs among the countries in the region [7]. In Iran, road traffic injuries rank as the second most prevalent cause of mortality, surpassed only by cardiovascular disease, and emerge as the primary contributor to years of life lost (YLL) [8]. In Iran, where the incidence of traffic accidents is estimated at around 600 per 100,000 population, resulting in approximately 400,000 accidents annually, the recorded statistics from 1997 to 2020 reveal a total of more than 5,760,000 road traffic injuries and about 472,000 fatalities [9, 10]. Traffic accidents not only pose a significant public health concern but also have substantial economic implications. The financial impact of road traffic injuries, encompassing medical expenses, lost productivity, and diminished quality of life, has been estimated to range between 2.18 and 8% of Iran's GDP [11, 12].

The assessment of road traffic accidents' safety profile involves gauging both the count of individuals injured and the mortality rate [3]. To assess preceding approaches and design impactful interventions and strategies for mitigating road traffic injuries and fatalities, it is imperative to comprehend the patterns and trends. On the other hand, analyzing this pattern among diverse population subgroups is instrumental in recognizing those particularly vulnerable. Several studies have investigated in this regard during different periods of time [13–15]. A recent study conducted by Sadeghian et al. investigated the patterns of fatal traffic accidents spanning from 1997 to 2020. However, a limitation of this study lies in its analysis of crude rates, neglecting the influence of the country's fertility decline on age composition [10, 16]. On the other hand, conventional methods employed by researchers to evaluate traffic accident trends often fail to capture non-linear patterns. In contrast, the growth mixture model, utilizing a quadratic or cubic link function, effectively addresses these non-linear trends. To overcome the limitations of previous research and provide up-to-date mortality rates comparable to those of other countries, this study aims to investigate the trend of age-adjusted mortality rates due to traffic accidents from 2006 to 2022 in Iran.

Methods

Data sources

This study is based on the collection and analysis of data recorded by the Iranian Legal Medicine Organization from 2006 to 2022. In compliance with legal requirements, all fatalities resulting from road traffic injuries are reported to the Legal Medicine Organization, which authorizes burial. Information regarding demographic variables such as education level, job, and other characteristics was gathered from the deceased individuals' relatives using a checklist administered during the case investigation. Population data from the Statistical Center of Iran were utilized to estimate the crude and age-standardized mortality rates. This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.PHNS.REC.1401.160).

Statistical analysis

Descriptive statistics were used to summarize the data, and for hypothesis testing, Cramér's V was reported to indicate the strength of the association between categorical variables.

To calculate age-standardized rates of traffic accident mortality, we used the direct standardization method. Age-specific mortality rates were first calculated for each age group by dividing the number of deaths by the population of that age group. These rates were then multiplied by the corresponding age-specific proportions from the

World Health Organization's standard population [17]. The sum of these expected deaths was then divided by the total standard population and multiplied by 100,000 to obtain the age-standardized mortality rate per 100,000 population. This method allows for a fair comparison of mortality rates over time and across different populations by accounting for variations in age distribution. The formula for direct standardization is as follows:

$$\mathrm{ASMR} = \frac{\sum_{i=1}^{n}\left(\frac{\mathrm{Deaths}_i}{\mathrm{Population}_i}, \times, \mathrm{Standard\ Population}_i\right)}{\sum_{i=1}^{n}\mathrm{Standard\ Population}_i} \times 100{,}000$$

Where:

- Deaths_i: Number of deaths in age group i.
- $\mathrm{Population}_i$: Population size of age group i.
- $\mathrm{Standard\ Population}_i$: Proportion of the WHO standard population in age group i.

Direct standardization was chosen over indirect methods because it allows direct comparability of rates across provinces and time periods, even when age structures differ significantly. The WHO standard population was selected due to its global applicability and alignment with prior road safety studies.

The latent class Growth Mixture Model (LCGMM) was utilized to evaluate trends and identify provinces with similar trend patterns in ASMR due to traffic accidents. This advanced statistical method was chosen for two key reasons: first, to capture significant non-linear trends, such as reverse J-shaped or U-shaped patterns, which traditional linear models often fail to detect; and second, to cluster provinces into distinct classes based on shared temporal trends. By grouping provinces with similar trends, the LCGMM provides a foundation for further investigation into potential common characteristics among these regions. Once the provinces were grouped, we examined whether they shared any underlying risk factors or contextual similarities (e.g., economic challenges, road infrastructure quality, enforcement of traffic laws). Based on these shared characteristics, tailored recommendations were developed for each group of provinces.This model can be expressed using multilevel model notation as follows [18]:

$$y_{it}^{k} = \eta_{i0}^{k} + \eta_{i1}^{k}\lambda_{t}^{k} + \epsilon_{it}^{k}$$

$$\eta_{i0}^{k} = \eta_{00}^{k} + \sum_{j}\beta_{0j}^{k}x_j + \sigma_{i0}^{k}$$

$$\eta_{i1}^{k} = \eta_{01}^{k} + \sum_{j}\beta_{1j}^{k}x_j + \sigma_{i1}^{k}$$

Here, y_{it}^{k} in the level-1 model represents the observed ASMR for province i at time t for latent class k. Parameters in both the level-1 and level-2 equations are class-specific. The two latent growth factors η_{i1}^{k} and η_{i0}^{k} are continuous latent variables representing the latent intercept and slope growth factors, respectively. λ_{t}^{k} represents time scores, which can be specified as linear or nonlinear polynomial functions of time. In this study, we fitted various models (linear, cubic spline, and quadratic) and found that cubic functions performed best for modeling the counts, while quadratic functions were most effective for modeling the age-standardized mortality rates (ASMRs). The residual term ϵ_{it}^{k} is a composite error term at time t, accounting for both random measurement error and time-specific influences of the i-th province in the k-th class.

At the level-2 model, the intercept coefficients η_{00}^{k} and η_{01}^{k} represent the overall mean levels of the initial outcome and the average rate of outcome change over time, respectively. The slope coefficients β_{0j}^{k} and β_{1j}^{k} are the fixed effects of covariates on the latent intercept and slope growth factors. The terms σ_{i0}^{k} and σ_{i1}^{k} are residuals representing between-province variations in the latent growth factors. Different models with 2 to 8 latent classes were fitted for provinces at the sub-national level using age-standardized mortality rates. Criteria such as AIC, BIC, log likelihood, and entropy were employed to evaluate model performance and select the best-fitting model. For data analysis and result presentation, we used Stata 17, the lcmm package in R, and ArcMap 10.8.2.

Results

Traffic accident statistics

From 2006 to 2022, Iran recorded 325,851 traffic accident deaths. The median age (IQR) of victims was 34 years (23–51) for males and 37 years (22–56) for females, with a statistically significant age difference between genders ($p < 0.001$, Wilcoxon rank-sum test). In terms of gender, the majority of the individuals were male (78.83%), while females constituted 21.17% of the total (Table 1). Regarding education levels, the data indicated that 24.77% were illiterate, 23.27% had elementary education, 21.14% had lower secondary education, 23.67% had high school education, and 7.15% had university education. Most individuals involved in accidents were residents of urban areas (67.85%), with the remaining 32.15% coming from rural areas. The job distribution among the individuals varied, with the largest groups being self-employed (30.89%), housekeepers (14.60%), workers (12.81%), and pupils (8.09%). Regarding marital status, single individuals made up 36.55% of the total, while married individuals accounted for 63.45%.

Out of the total number of accidents that occurred during the studied period, 208,021 cases (63.84%) of deaths were related to accidents that happened on intercity

Table 1 Demographic characteristics of traffic accident mortality victims in Iran (2006–2022), stratified by road type, gender, education level, residence area, job, and marital status

Variable	Urban Roads (*n*, %)	Intercity Roads (*n*, %)	Rural Unpaved Roads (*n*, %)	Unknown Location (*n*, %)	Total (*n*, %)	Test
Age (Median-IQR)	36.00 (22–61)	34.00 (23–49)	31.00 (20–49)	32.00 (20–48)	34 (23–69)	< 0.001*
Gender						0.05φ
Male	73,852 (28.75)	160,295 (62.40)	20,571 (8.01)	2,155 (0.84)	256,873 (78.83)	
Female	16,513 (23.94)	47,726 (69.19)	4,288 (6.22)	451 (0.65)	68,978 (21.17)	
Total	90,365 (27.73)	208,021 (63.84)	24,859 (7.63)	2,606 (0.80)	325,851 (100.00)	
Education Level						0.05φ
Illiterate	22,469 (30.49)	43,294 (58.75)	7,231 (9.81)	700 (0.95)	73,694 (24.77)	
Elementary Education	19,066 (27.54)	43,505 (62.84)	6,150 (8.88)	506 (0.73)	69,227 (23.27)	
Lower Secondary Education	16,467 (26.18)	41,027 (65.23)	4,958 (7.88)	447 (0.71)	62,899 (21.14)	
High School Education	19,784 (28.10)	46,061 (65.42)	4,116 (5.85)	447 (0.63)	70,408 (23.67)	
University Education	5,255 (24.72)	15,086 (70.95)	822 (3.87)	99 (0.47)	21,262 (7.15)	
Total	83,041 (27.91)	188,973 (63.52)	23,277 (7.82)	2,199 (0.74)	297,490 (100.00)	
Residence Area						0.30φ
Urban	50,967 (35.11)	87,863 (60.52)	5,383 (3.71)	961 (0.66)	145,174 (67.85)	
Rural	7,468 (10.86)	49,889 (72.53)	10,721 (15.59)	705 (1.02)	68,783 (32.15)	
Total	58,435 (27.31)	137,752 (64.38)	16,104 (7.53)	1,666 (0.78)	213,957 (100.00)	
Job						0.14φ
Pupil	7,051 (29.48)	14,107 (58.98)	2,569 (10.74)	190 (0.79)	23,917 (8.09)	
Student (University)	2,576 (29.13)	5,773 (65.28)	457 (5.17)	38 (0.43)	8,844 (2.99)	
Housekeeper	10,764 (24.93)	29,589 (68.53)	2,573 (5.96)	250 (0.58)	43,176 (14.60)	
Government Employee	3,282 (23.30)	10,126 (71.90)	608 (4.32)	67 (0.48)	14,083 (4.76)	
Worker	12,102 (31.94)	21,797 (57.53)	3,615 (9.54)	371 (0.98)	37,885 (12.81)	
Self-Employed	26,278 (28.76)	58,100 (63.58)	6,305 (6.90)	694 (0.76)	91,377 (30.89)	
Soldier	1,151 (34.21)	1,919 (57.03)	271 (8.05)	24 (0.71)	3,365 (1.14)	
Retired	7,301 (50.28)	6,692 (46.08)	457 (3.15)	71 (0.49)	14,521 (4.91)	
Unemployed	3,620 (32.88)	6,294 (57.17)	1,013 (9.20)	82 (0.74)	11,009 (3.72)	
Driver	1,812 (12.20)	12,416 (83.63)	553 (3.72)	66 (0.44)	14,847 (5.02)	
Farmer	2,945 (15.95)	12,021 (65.09)	3,348 (18.13)	155 (0.84)	18,469 (6.24)	
Military	329 (18.68)	1,328 (75.41)	94 (5.34)	10 (0.57)	1,761 (0.60)	
Other	3,164 (25.23)	8,101 (64.60)	1,154 (9.20)	122 (0.97)	12,541 (4.24)	
Total	82,375 (27.85)	188,263 (63.65)	23,017 (7.78)	2,140 (0.72)	295,795 (100.00)	
Marital Status						0.05φ
Single	23,358 (29.72)	47,758 (60.77)	6,750 (8.59)	728 (0.93)	78,594 (36.55)	
Married	35,120 (25.74)	90,884 (66.61)	9,458 (6.93)	974 (0.71)	136,436 (63.45)	
Total	58,478 (27.20)	138,642 (64.48)	16,208 (7.54)	1,702 (0.79)	215,030 (100.00)	

* *P*-value for Kruskal-Wallis Test

φ Cramer's V Coefficient

roads. The number of urban road victims was 90,365 (27.73%), and 24,859 (7.63%) deaths were related to accidents on rural roads.

Most deaths occurred at the scene (51.72%), during transfer to the hospital (7.59%), or at the hospital (40.32%). Drivers constituted 42.20% of the victims, followed by pedestrians at 35.00% and passengers at 22.80%. Vehicle-to-vehicle collisions were the most common accident mechanism, accounting for 47.60% of deaths, followed by vehicle-pedestrian collisions (22.90%) and vehicle overturns (22.80%). Most accidents occurred at night (57.20%), followed by the day (32.90%) and twilight (9.90%). Ambulances transported 87.10% of victims. The leading cause of death was head trauma (54.40%), followed by multiple trauma (29.00%) and bleeding (7.70%, Table S1).

Critical associations in traffic mortality

There was a very strong association between the type of victim and the road type (Cramér's V = 0.27, Table S1). On urban roads, passengers were the predominant victims (46.80%), while on intercity roads, drivers accounted for the largest share (43.20%). In contrast, rural unpaved roads showed drivers as the primary victims (50.80%).

Similarly, the accident mechanism demonstrated a very strong association with road type (Cramér's V = 0.28).

Vehicle-pedestrian collisions were the most frequent on urban roads (47.00%), while vehicle-to-vehicle collisions predominated on intercity roads (52.40%), and vehicle overturns were common on rural unpaved roads (31.50%).

A strong association was found between the place of death and road type (Cramér's V = 0.18), with most deaths occurring at the scene on intercity roads (60.03%) and at hospitals on urban roads (58.69%).

Residence area also had a very strong association with road type (Cramér's V = 0.31), with the majority of victims on urban roads residing in urban areas (35.11%), while those on intercity and rural unpaved roads mostly came from rural areas (72.53% and 15.59%, respectively).

In contrast, variables such as gender, education level, marital status, and transport mode for the victim showed weak or very weak associations with road type, indicating that they do not have substantial conceptual importance in this analysis.

Descriptive trends

From 2006 to 2022, traffic accident deaths in Iran showed an overall decline with notable fluctuations at key points. In 2006, there were 26,780 deaths, with a crude rate of 38.86 and an adjusted rate of 41.26. By 2012, deaths had decreased to 19,052, with a crude rate of 25.12 and an adjusted rate of 25.54. This downward trend continued, reaching 16,173 deaths in 2017, with crude and adjusted rates of 19.85 and 20.30, respectively (Table 2). In 2019 (at the same time as the beginning of the COVID-19 pandemic), deaths slightly increased to 16,896, with a crude rate of 20.49 and an adjusted rate of 20.98. The lowest point was in 2020, with 15,343 deaths, a crude rate of 18.38, and an adjusted rate of 18.75. However, by 2022, deaths rose again to 19,517, with the crude rate increasing to 23.00 and the adjusted rate to 23.40.

Country-Level traffic accident trends: analysis using growth mixture models

When considering all road types, the number of traffic accident victims showed a decreasing trend until 2017. However, since 2018, an increasing trend has been observed, as estimated by the cubic model. This pattern is consistent for both intercity and urban roads. In contrast, rural unpaved roads experienced a decline in traffic accidents from 2010 to 2016, after which the trend stabilized, showing neither an increase nor a decrease (Figure S1).

The country-level trend of age-standardized mortality rates due to traffic was evaluated using a growth mixture model with one trajectory. The results indicate a reverse J-shaped trend overall (Fig. 1). The average initial mortality rate (intercept) was 48.13 (SE = 1.32, $p < 0.001$). The negative slope of -3.67 (SE = 0.34, $p < 0.001$) suggests a decreasing trend initially, while the positive quadratic term of 0.14 (SE = 0.02, $p < 0.001$) indicates an upward turn in recent years.

For males, the trend was more pronounced with a higher initial rate (intercept of 73.87, SE = 1.85, $p < 0.001$), a steeper decline (slope of -5.95, SE = 0.47, $p < 0.001$), and a significant upward turn indicated by the quadratic term of 0.24 (SE = 0.03, $p < 0.001$). Female victims had a lower initial rate (intercept of 22.01, SE = 0.92, $p < 0.001$) and a

Table 2 Yearly traffic accident mortality rates in Iran (2006–2022), showing crude and age-standardized rates for males, females, and overall populations. Rates declined from 38.86 per 100,000 in 2006 to 19.85 in 2017 but increased to 23.00 in 2022, highlighting a concerning resurgence after years of improvement

Year	Female			Male			Overall		
	Count	Crude Rate	Adjusted Rate	Count	Crude Rate	Adjusted Rate	Count	Crude Rate	Adjusted Rate
2006	5342	15.62	18.17	21,438	61.75	63.97	26,780	38.86	41.26
2007	4600	13.56	15.49	17,761	50.75	52.11	22,361	32.44	34.06
2008	4741	13.80	15.39	18,034	51.07	52.36	22,775	32.69	34.08
2009	4809	13.77	14.11	17,830	49.97	48.74	22,639	32.06	31.53
2010	4854	13.73	14.94	18,308	50.72	51.50	23,162	32.41	33.32
2011	4442	11.93	12.71	15,592	41.16	41.43	20,034	26.68	27.11
2012	4096	10.91	11.59	14,956	39.06	39.38	19,052	25.12	25.54
2013	4089	10.78	11.36	13,855	35.75	36.17	17,944	23.40	23.83
2014	3812	9.93	10.44	13,036	33.20	33.68	16,848	21.70	22.13
2015	3776	9.72	10.21	12,784	32.09	32.51	16,560	21.04	21.43
2016	3459	8.77	9.10	12,456	30.76	31.35	15,915	19.91	20.34
2017	3489	8.69	9.00	12,684	30.70	31.40	16,173	19.85	20.30
2018	3720	9.05	9.27	13,418	31.68	32.66	17,138	20.53	21.11
2019	3686	9.07	9.39	13,210	31.58	32.60	16,896	20.49	20.98
2020	2697	6.54	6.55	12,646	29.94	30.75	15,343	18.38	18.75
2021	3301	8.08	8.13	13,413	31.72	32.71	16,714	20.10	20.65
2022	4065	9.68	9.65	15,452	36.04	37.83	19,517	23.00	23.40

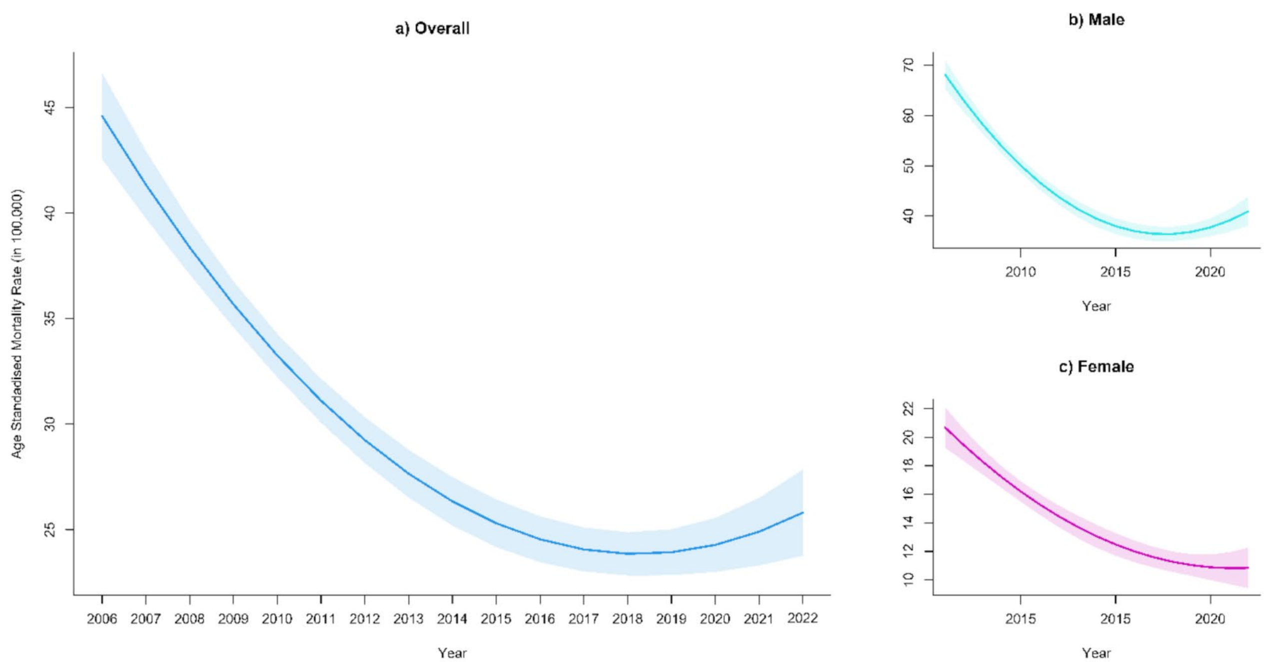

Fig. 1 A reverse J-shaped trend in Iran's national-level age-standardized traffic accident mortality rates (2006–2022) is shown for (**a**) overall, (**b**) male, and (**c**) female populations. Derived from a latent class growth mixture model with one trajectory, the trend shows an initial decline (intercept: 48.13, slope: -3.67) followed by a significant upward turn (quadratic term: 0.14, $p < 0.001$), highlighting a concerning resurgence after years of improvement

milder decline (slope of -1.37, SE = 0.24, $p < 0.001$), with a slight increase later (quadratic term of 0.04, SE = 0.01, $p < 0.001$, See Table S2).

Identifying provinces with similar traffic accident trends using latent class growth mixture models

Considering AIC, BIC, log-likelihood, and entropy collectively, the model with six classes for the ASMRs among both genders (overall) performed the best. However, when analyzing the ASMRs for males and females separately, the seven-class models yielded the best performance (Table S3). The latent class growth mixture model with six classes for overall traffic accident data reveals distinct trends across Iranian provinces. Provinces in Class 1 (Sistan & Baluchestan, Markazi, Kerman) start with a high initial accident rate, with an intercept of 54.94, and exhibit a moderate decline over time, characterized by a slope of -3.23 (Fig. 2). Class 2 includes only one province, Semnan, which has a very high initial accident rate (intercept of 88.91) and shows a pronounced reduction in trends, with a slope of -5.56. Class 3 (Khuzestan, Razavi Khorasan, Ardebil, East Azerbaijan, West Azerbaijan, Isfahan) displays an intermediate pattern with moderate initial rates (intercept of 39.02) and a slight downward trend, indicated by a slope of -3.43. Class 4 provinces (e.g., Yazd, Zanjan, Lorestan, Qazvin, Qom, Hamedan, North Khorasan, South Khorasan, Bushehr, Fars) have moderate initial rates (intercept of 53.50) and experience steady declines over time, with a slope of -3.90. Class 5 provinces, including Tehran and Alborz, are marked by lower initial accident rates (intercept of 29.31) and a more pronounced downward trajectory, with a slope of -3.34. Finally, Class 6 provinces, including Kohgiluyeh & Boyer-Ahmad, Kurdistan, Mazandaran, Golestan, Hormozgan, Ilam, Kermanshah, Chaharmahal & Bakhtiari, and Gilan, start with lower initial rates (intercept of 45.49) and exhibit moderate declines over time, with a slope of -3.55 (Table S4). The results of similar models for ASMR among males and females are available in the supplementary material (Figures S2 and S3).

Province-Level trends

Conducting a growth mixture model separately for each province revealed that the majority of provinces exhibit a reverse J-shaped trend in traffic accident mortality. However, Sistan and Baluchestan, as well as Kohgiluyeh and Boyer-Ahmad, deviate from this pattern. These two provinces display a U-shaped trend in traffic accident mortality, highlighting a distinct and concerning variation compared to the general trend observed across the other regions (Fig. 3).

Discussion

This study assessed trends in age-standardized mortality rates due to traffic accidents in Iran from 2006 to 2022. Utilizing a growth mixture model, it focused on uncovering non-linear trends and examining both temporal

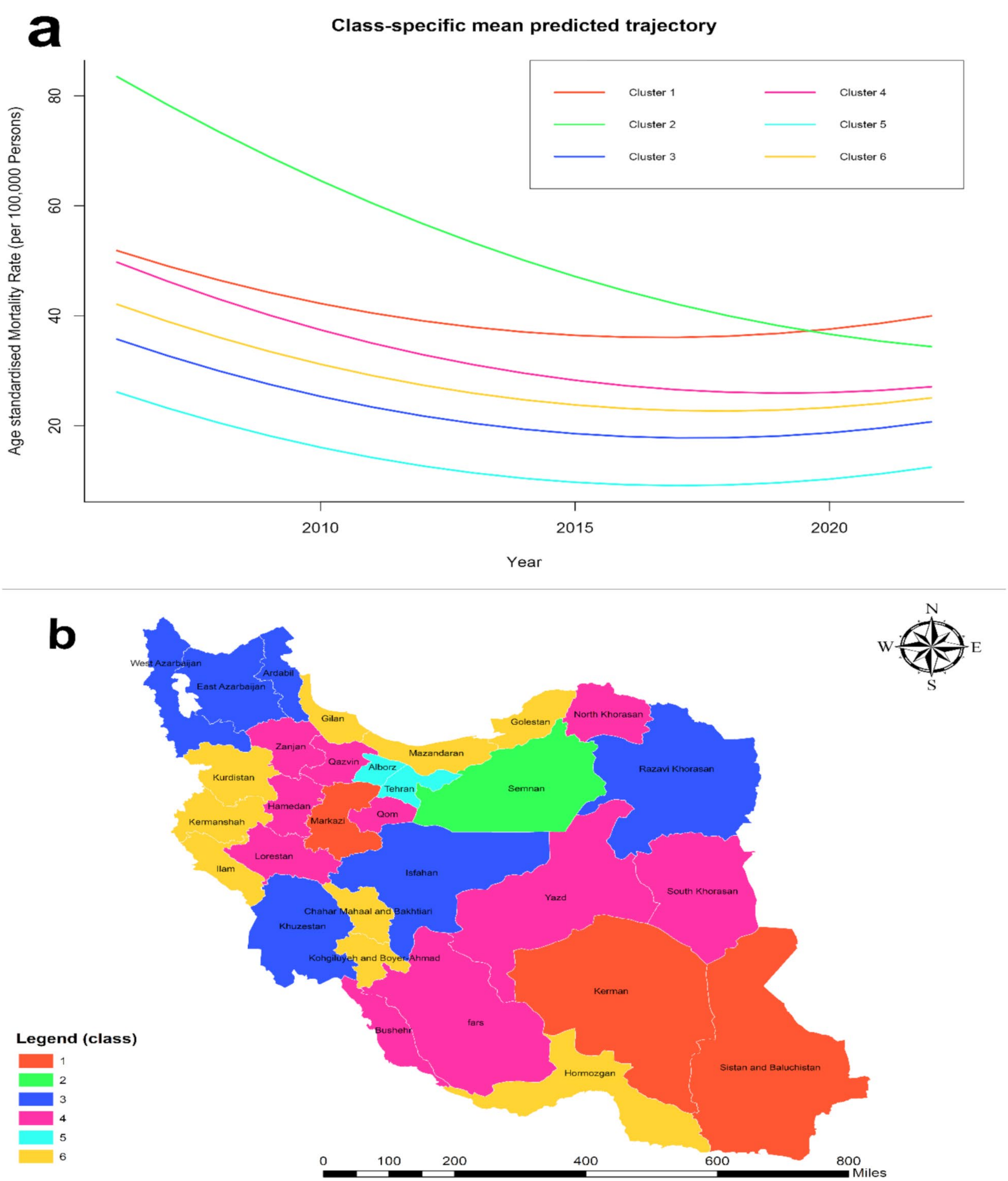

Fig. 2 (**a**) Latent class growth mixture model for overall traffic accident mortality trends by province (2006–2022), identifying six distinct classes with unique temporal patterns, such as high initial rates with moderate declines (Class 1: Sistan & Baluchestan, Markazi, Kerman) and sharp reductions from high baselines (Class 2: Semnan). (**b**) Map of Iranian provinces categorized by latent class, illustrating the geographic distribution of provinces within each class and emphasizing regional disparities in traffic accident mortality trends

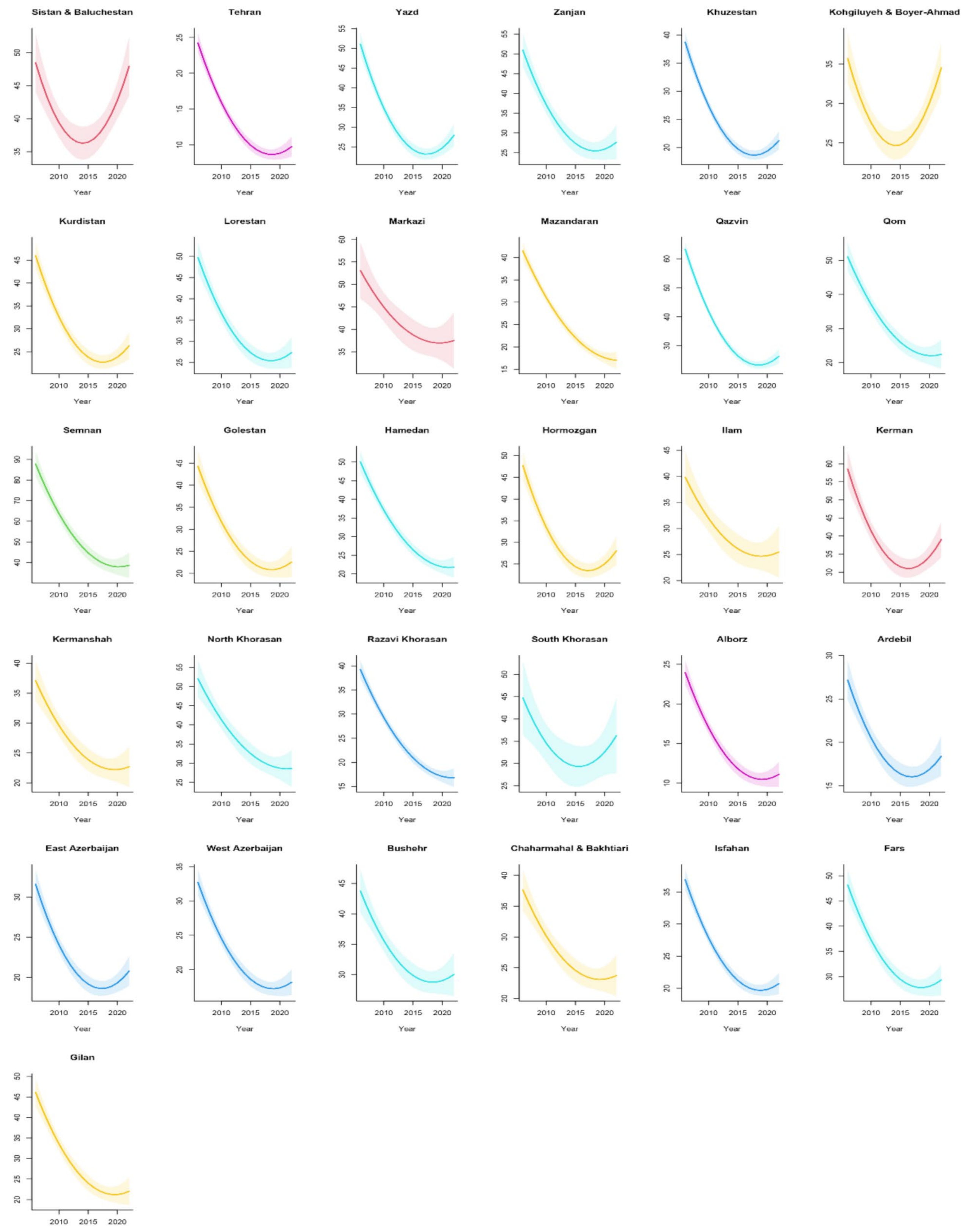

Fig. 3 Province-Level Traffic Accident Mortality Trends in Iran (2006–2022), Revealing a Reverse J-Shaped Pattern in Most Provinces and a U-Shaped Trend in Sistan and Baluchestan, and Kohgiluyeh and Boyer-Ahmad. Each figure represents the output of a single trajectory latent class growth mixture model performed at the provincial level

changes and regional differences across provinces. Our analysis revealed a reverse J-shaped trend at the national level, characterized by an initial decline in mortality rates followed by a recent increase. This trend was more pronounced among males compared to females. At the provincial level, most regions exhibited a reverse J-shaped pattern; however, Sistan and Baluchestan, along with Kohgiluyeh and Boyer-Ahmad, were exceptions, showing a U-shaped trend. These findings highlight a concerning resurgence in traffic accident mortality rates after years of decline, underscoring the need for targeted interventions to address the recent upward shift in fatalities.

The analysis of the age-standardized death rate due to traffic accidents showed that this rate has been increasing since 2017 after a decrease from 2006 to 2017. The observed decrease in traffic mortality rates from 2006 to 2017 can be attributed to several factors, including improved road safety measures, stricter traffic laws, and increased emergency medical services. The enforcement of speed limits, seat belt, and helmet laws, along with public awareness campaigns, likely contributed to this initial decline [19].

The comparison of the results of this study aligns with the study by Sadeghian et al., who also identified a decrease 2 (from 2005 to 2020) in the death rate from traffic accidents in Iran, though their analysis did not consider changes in age composition as this study does [10]. In addition, one of the strengths of our study is the use of the quadratic model, which is used to detect non-linear trends.

This pattern of changes is consistent with previous studies in Iran and other countries in the EMRO region, which have reported an increase in the death rate due to traffic accidents in recent years [20]. This increase can be caused by various factors, including the rise in the number and speed of vehicles, risky driving behaviors, inadequate transportation infrastructure, and the failure to fully implement safety laws.

One key reason for the recent rise in traffic accident mortality in Iran is significant economic hardship, marked by rising inflation and reduced household purchasing power [21]. These challenges have impacted road safety, as financial constraints can lead to delayed vehicle repairs, increased reliance on motorcycles, adoption of substandard parts, or prolonged utilization of older, unsafe vehicles [22, 23]. To address this, policymakers can implement measures like subsidies or low-interest loans for safety upgrades, free vehicle inspections to identify risks, and scrappage programs offering cash incentives to replace aging vehicles. Particularly important are public awareness campaigns emphasizing the cost-saving benefits of preventive maintenance (e.g., avoiding costly accidents) and promoting affordable safety gear, such as helmets and seat belts. By combining financial incentives, infrastructure improvements, and education, Iran can mitigate the impact of economic hardship on road safety and reverse the resurgence in traffic fatalities since 2017.

Additionally, the age-standardized death rate in 2020 was at its lowest level, which is comparable to the increase in COVID-19 during that year, likely due to reduced travel and policies aimed at limiting movement, such as fines, which led to a decrease in the death rate. According to the report of the Iranian Statistics Center, the total number of trips made in 2019 has decreased by 10% compared to 2018, and this decrease in the number of accidents has continued to the point that in 2021, the total number of trips had dropped to 20% of what it was in 2018 [24]. In the hypothetical situation, if there was no COVID-19 and the number of trips did not decrease, Probably, the increasing slope in recent years was much steeper than what it is now. A study in Turkey also reported that in April, when the strictest quarantine measures were applied for the entire month, traffic accidents decreased by almost 60%, deaths by 43%, and injuries decreased significantly [25].

Our data show higher mortality rates on urban roads compared to rural, mirroring findings from other low- and middle-income countries (LMICs) where rural road safety is often a lower priority. In these areas, factors such as poor road conditions, a lack of emergency medical services, and less enforcement of traffic laws contribute to the increased death rate [26].

Differences in healthcare infrastructure and emergency response capabilities also play an important role. For example, higher death rates in rural areas compared to urban centers can be partially explained by delays in medical response times and the severity of injuries sustained in high-speed crashes on interurban roads. Similar studies in the EMRO region have also recorded an increasing trend in traffic accident fatalities despite an initial decline. For instance, research in neighboring countries such as Saudi Arabia and Pakistan [27, 28] has shown parallel trends where infrastructure improvements and enforcement of traffic laws initially reduced the mortality rate, but socio-economic factors and increased vehicle ownership subsequently contributed to an increase in fatalities.

Provinces such as Sistan & Baluchestan, Markazi, and Kerman (Class 1), along with Kohgiluyeh & Boyer-Ahmad (xhibiting U-shaped trends), experience higher and more variable mortality rates. While these trends are evident, the underlying reasons remain uncertain. Possible contributing factors could include economic challenges, suboptimal road conditions, and inconsistent enforcement of traffic regulations. These regions also face issues such as limited emergency medical services, less reliable rural road networks, and restricted access to safer vehicles, which might play a role in the observed trends

[29, 30]. Solutions for provinces in this class include road upgrades, community education, and subsidies for vehicle safety improvements.

Class 3 provinces (Khuzestan, Razavi Khorasan, etc.) show moderate rates with slight declines, which might be driven by urbanization and population growth. Studies show that urbanization, particularly in rapidly growing megacities, increases road traffic accidents due to factors like population growth, economic activity, and changes in physical infrastructure [31]. Improving urban road design, promoting public transit, and implementing sustainable urban planning are essential.

Class 5 provinces (Tehran, Alborz) have lower rates and significant declines, likely benefiting from advanced infrastructure and public transit. Continued investment in pedestrian safety and public awareness campaigns is crucial to maintain progress. These regions can serve as models for others.

Semnan (Class 2) initially exhibited a high rate of traffic accident mortality, likely due to its role as a critical transit hub between Tehran and Esfahan—the latter being Iran's second most industrialized and economically significant city after Tehran. This position results in a high volume of intercity travel along the Semnan-Tehran and Semnan-Esfahan routes. However, the road infrastructure in Semnan province has historically been inferior to that of Tehran and Esfahan, which may explain the province's elevated rate of fatal intercity traffic accidents [32]. The sharp decline in mortality rates in recent years is likely attributed to stricter law enforcement and significant infrastructure improvements. This success offers valuable lessons for other high-risk areas.

Class 6 provinces (Kurdistan, Mazandaran, etc.), particularly tourist destinations in this class like Mazandaran, Gilan, and Ardabil, face seasonal risks due to high tourist traffic and geographic challenges [33]. To address these, targeted measures such as seasonal traffic controls (e.g., increased patrols and dynamic speed limits), multilingual safe driving campaigns for tourists, and improved rural road infrastructure in high-traffic areas are essential. Additionally, collaboration with tourism operators to provide shuttle services can reduce private vehicle use, mitigating risks while supporting sustainable tourism.

Tailored interventions are key: addressing structural inequalities in poorer provinces, upgrading infrastructure in urban areas, and targeting seasonal and geographic risks in tourist regions. These strategies can help reverse rising fatality trends and achieve sustainable reductions in traffic accident mortality.

Despite the fact that this study was carried out based on the data of the Forensic Medicine Organization of Iran, which has provided the most complete data in the field of accidents, this study has several limitations. If the total numner of intraurban and extraurban trips was known, more accurate results could be obtained by using this total as the denominator of mortality rates. Another limitation was that only the outcome variable, i.e., the death rate for each province, was included in the model, without other effective covariates. Additionally, the study did not account for other potential confounding factors, such as changes in traffic volume, socioeconomic conditions, and improvements in healthcare during the study period. It is suggested that future studies should examine various factors affecting this process, such as demographic characteristics, risky driving behaviors, and the quality of transportation infrastructure, to find more effective solutions to reduce deaths caused by traffic accidents.

Conclusion

This study reveals a concerning resurgence in traffic accident mortality rates in Iran after a decade of decline (2006–2017), with a sharp rise since 2017, particularly on intercity roads. Key drivers of this increase might include economic hardship, delayed vehicle maintenance, reliance on older or unsafe vehicles, and inconsistent enforcement of safety regulations. To reverse this trend, policymakers must prioritize targeted interventions that combine financial incentives, such as subsidies and low-interest loans, to encourage vehicle safety upgrades and modernization. Free inspections can help identify high-risk vehicles, while scrappage programs can facilitate the replacement of aging fleets. Public awareness campaigns should emphasize the cost-saving benefits of preventive maintenance and promote affordable safety gear, such as helmets and seat belts. Additionally, localized strategies are essential to address regional disparities, including infrastructure upgrades in high-mortality provinces like Sistan-Baluchestan and seasonal traffic controls in tourist regions. Provinces exhibiting U-shaped trends require urgent attention to improve road quality, enhance emergency services, and strengthen enforcement. Without proactive, region-specific policies, Iran risks worsening its traffic safety crisis. A renewed commitment to infrastructure development, education, and equitable enforcement is critical to reducing fatalities and aligning with global road safety goals.

Abbreviations

ASMR	Age-Standardized Mortality Rate
DALY	Disability-Adjusted Life Years
EMRO	Eastern Mediterranean Regional Office (of the WHO)
GDP	Gross Domestic Product
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
IQR	Interquartile Range
LCGMM	Latent Class Growth Mixture Model
LMICs	Low-and Middle-Income Countries
RTA	Road Traffic Accident
SE	Standard Error
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1

Author contributions

MRT contributed to the conceptualization, methodology, and data analysis. Farzad Maleki handled data curation, statistical analysis, and manuscript drafting. MT assisted with the literature review and interpretation of results. MRV contributed to study design and manuscript revision. SDM supported findings interpretation. MF participated in data analysis and manuscript revision, while SSHN supervised the study, conceptualized the research, and provided final manuscript approval. All authors have read and approved the final manuscript.

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Data availability

The data supporting the findings of this study are available upon reasonable request from corresponding author.

Declarations

Ethics approval and consent to participate

Ethics approval and consent to participate: This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.PHNS.REC.1401.160). The data used in this research were obtained from the Iranian Legal Medicine Organization, which records all traffic accident-related fatalities. While individual informed consent was not applicable due to the use of secondary anonymized data, permission to access and analyze the data was formally granted by the relevant authorities. All data handling adhered to strict confidentiality and data protection protocols, ensuring compliance with ethical guidelines and regulations. The study followed the principles outlined in the Declaration of Helsinki, and measures were taken to protect the privacy of individuals involved in the records.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Fisa R, Musukuma M, Sampa M, Musonda P, Young T. Effects of interventions for preventing road traffic crashes: an overview of systematic reviews. BMC Public Health. 2022;22(1):513.
2. Bakhtiyari M, Soori H. Epidemiology of traffic crashes outcomes and related factors. Irtiqa Imini Pishgiri Masdumiyat (Safety Promotion Injury Prevention). 2013;1(3):150–9.
3. Organization WH. Global status report on road safety 2015. World Health Organization; 2015.
4. Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019. Lancet. 2020;396(10258):1204–22.
5. Peden MM. World report on road traffic injury prevention. World Health Organization; 2004.
6. Organization WH. Road traffic injuries 2023 [updated 13 December 2023. Available from: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries
7. Akbari M, Naghavi M, Soori H. Epidemiology of deaths from injuries in the Islamic Republic of Iran. EMHJ-Eastern Mediterranean Health Journal, 12 (3–4), 382–390, 2006. 2006.
8. Saadat S, Yousefifard M, Asady H, Moghadas Jafari A, Fayaz M, Hosseini M. The most important causes of death in Iranian population; a retrospective cohort study. Emerg (Tehran). 2015;3(1):16–21.
9. Akbari H, Mahdian M, Motalebi M, Asgarian FS. Epidemiology, Incidence and Trend of Injuries in Iran: A National Study. 2021.
10. Sadeghian F, Mehri A, Ghodsi Z, Baigi V, Bardsiri MS, Sharif-Alhoseini M, et al. Road traffic injuries and associated mortality in the Islamic Republic of Iran. East Mediterr Health J. 2023;29(10):796–803.
11. Behnood HR, Haddadi M, Sirous S, Ainy E, Rezaei R. Medical costs and economic burden caused by road traffic injuries in Iran. Trauma Monthly. 2017;22(2).
12. Mahdian M. The economic burden of road traffic accidents in Iran: the time to sound the alarm. Archives Trauma Res. 2018;7(2):37–8.
13. Hasanzadeh J, Moradinazar M, Najafi F, Ahmadi-Jouybary T. Trends of mortality of road traffic accidents in Fars Province, Southern Iran, 2004–2010. Iran J Public Health. 2014;43(9):1259.
14. Sadeghi-Bazargani H, Ayubi E, Azami-Aghdash S, Abedi L, Zemestani A, Amanati L et al. Epidemiological patterns of road traffic crashes during the last two decades in Iran: a review of the literature from 1996 to 2014. Archives Trauma Res. 2016;5(3).
15. Moradi A, Rahmani K. Trend of traffic accidents and fatalities in Iran over 20 years (1993–2013). J Mazandaran Univ Med Sci. 2014;24(119):223–34.
16. Roudi F, Azadi P, Mesgaran M. Iran's population dynamics and demographic window of opportunity. Domest Econ. 2017.
17. Ahmad OB, Boschi Pinto C, Lopez A, Murray C, Lozano R, Inoue M. Age Standardization of Rates: A New WHO Standard. GPE Discussion Paper Series, EIP/GPE/EBD, World Health Organization. 2001;No.31.
18. Wang J, Wang X. Structural Equation Modeling: Applications Using Mplus. 2nd Edition ed: Wiley; 2019.
19. Delavary Foroutaghe M, Mohammadzadeh Moghaddam A, Fakoor V. Impact of law enforcement and increased traffic fines policy on road traffic fatality, injuries and offenses in Iran: interrupted time series analysis. PLoS ONE. 2020;15(4):e0231182.
20. Mollaei Pardeh M, Yarmohammadian MH, Atighecian G, Ebrahimi A, Maracy MR. 11-Year trend of mortality from fatal road traffic injuries in the center of Iran; a Cross-sectional study. Arch Acad Emerg Med. 2024;12(1):e27.
21. Tarnabi FS, Raghfar H. The impact of inflation on inequality and income distribution in Iran by emphasizing expenditure centile. Int J Industrial Eng Oper Res. 2025;7(1):27–45.
22. Kwaghgba G, Aondofa T. The effect of economic policies on urban transport patterns: A review of motorcycle usage for urban mobility in Nigeria. Journal of Sustainable Development of Transport and Logistics; 2024.
23. Kayisu AK, El Bahnasawi M, Mikušová M, Egbine K, Alsisi M, Kambale WV, et al. Navigating chaos: A qualitative system Dynamics-based analysis of road safety challenges for vulnerable road users in a major developing City (Kinshasa). WSEAS Transactions on Environment and Development; 2024.
24. [Available from: https://amar.org.ir/statistical-information/statid/22499
25. Oguzoglu U. COVID-19 lockdowns and decline in traffic related deaths and injuries. 2020.
26. Staton C, Vissoci J, Gong E, Toomey N, Wafula R, Abdelgadir J, et al. Road traffic injury prevention initiatives: a systematic review and metasummary of effectiveness in low and middle income countries. PLoS ONE. 2016;11(1):e0144971.
27. Khan AA, Fatmi Z. Strategies for prevention of road traffic injuries (RTIs) in Pakistan: situational analysis. J Coll Physicians Surg Pakakistan. 2014;24(5):356.
28. Mansuri FA, Al-Zalabani AH, Zalat MM, Qabshawi RI. Road safety and road traffic accidents in Saudi Arabia: A systematic review of existing evidence. Saudi Med J. 2015;36(4):418.
29. Rad M, Martiniuk AL, Ansari-Moghaddam A, Mohammadi M, Rashedi F, Ghasemi A. The pattern of road traffic crashes in South East Iran. Glob J Health Sci. 2016;8(9):51677.
30. Behzadi Goodari M, Sharifi H, Dehesh P, Mosleh-Shirazi MA, Dehesh T. Factors affecting the number of road traffic accidents in Kerman Province, southeastern Iran (2015–2021). Sci Rep. 2023;13(1):6662.
31. Iamtrakul P, Hokao K, The study of urbanization patterns and their impacts on, road safety. Lowland Technol International: Official J Int Association Lowland Technol. 2012;14:60–9.

32. Alizadeh A, Zare M, Darparesh M, Mohseni S, Soleimani-Ahmadi M. GIS based analysis of intercity fatal road traffic accidents in Iran. J Med Life. 2015;8(Spec Iss 2):77–82.
33. Omidi MR, Eskandari MJ, Raissi S, Shojaei AA. Providing an appropriate prediction model for traffic accidents: A case study on accidents in Golestan, Mazandaran, Guilan, and ardebil provinces. Health in Emergencies & Disasters Quarterly; 2019.

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