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RESEARCH ARTICLE

Fifty Years of Motor Vehicle Crashes in Saudi Arabia: A Way Forward

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Abstract:

Introduction:

This study involves an in-depth assessment of the state of traffic safety across the Kingdom of Saudi Arabia over the last fifty years.

Methods:

A comprehensive dataset of 59 published peer-reviewed journal articles, as well as 212 government reports and official statistics, was collated and critically assessed to determine major factors affecting traffic safety in the country.

Results and Discussion:

Results reveal that some traffic safety indicators are still showing worsening trends despite the great efforts to improve road safety in Saudi Arabia, while few other areas have either stabilized or started showing some improvements over recent years. Findings also show that human losses (estimated to be 4.7% among all mortalities) and economic losses (estimated to be as high as $16b annually) are significantly higher than developed and most developing countries. Contributing factors to the high losses include risky behaviors of drivers and road users, speeding, unrestrained seatbelts, use of handheld electronic devices and/or mobile phones, high motor vehicle ownership rate, and others.

Conclusion:

It can be concluded that various traffic safety indicators have been giving mixed signs in Saudi Arabia over the last fifty years, and a change in safety behavior among road users is needed along with new strategies to minimize motor vehicle crashes.

Keywords: Motor vehicle crashes, Human and economic losses, Behavior of road users, Sustainable road transportation, Passengers, Road safety.

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1. INTRODUCTION

Motor vehicles are an important mode of transporting passengers and goods. However, motor vehicle crashes (MVCs) claimed the lives of 1.25 million people worldwide in 2013, and are the primary cause of death among those aged 15-29. They are the ninth leading cause of death across all age groups globally and are forecasted to become the seventh foremost cause of death by 2030 [1]. Although preventing all the MVCs is not possible, minimizing their numbers and harmful consequences is achievable by implementing well-crafted intervention measures [2, 3].

The Kingdom of Saudi Arabia (KSA) is a country in Southwestern Asia with a total area of 2,250,000 square kilometers [4]. Its population has increased six times in the last four decades, reaching 31.7 million in 2017. This country has experienced an oil boom over the same period that brought a significant increase in economic growth and living standards. It has also resulted in an inflow of expatriates who go there to work. Currently, those expatriates constitute about 37% of the KSA population [5].

The economic prosperity experienced in KSA has led to tremendous changes to its road network and the number of motor vehicles. The length of asphalted road networks has increased from 239 km in 1952 to approximately 64,632 km currently. The number of motor vehicles also has increased exponentially from 145,000 in 1970 to almost 18 million currently with approximately 800,000 vehicles being imported every year [5 - 9].

In KSA, several government organizations and agencies,

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such as the General Directorate of Traffic (GDT), Ministry of Transportation (MoT), Ministry of Health (MoH), Saudi Red Crescent Society (SRCS), municipalities and others, are involved in road traffic safety. GDT was established in 1960, under the Ministry of Interior (MoI), to take responsibility for traffic regulations and surveillance, driver education, vehicle testing, and collision reporting. Motor vehicle periodic inspection program (MVPI) has been in place since 1985, where each motor vehicle on the road is inspected annually to be roadworthy. Third-party insurance and seatbelt use for both drivers and front-seat passengers were made obligatory in 2002 [2, 7, 8, 10].

Globally, the problem of MVCs has attracted enormous attention in terms of research and safety interventions in the second half of the last century. This resulted in massive reductions in the size of the problems in terms of the number of MVCs and the resulting human losses in most developed countries, such as North America [11, 12], Australia [13], and the United Kingdom [14]. In contrast, many developing countries have experienced the opposite results. In KSA, the number of MVCs and the resulting human and financial losses are still enormous.

Official statistics show that 5,754 people were killed and 32,910 were injured as a result of the 287,781 crashes that happened on Saudi roads in 2019 [7]. Moreover, researchers estimate that 2.2% to 4.7% of the gross domestic product (GDP) is lost every year due to the MVCs. It was also estimated that over one million people died and were seriously injured in motor vehicle crashes during 1970-2008. This figure represented about 4% of the KSA population in 2008 [6, 7]. These losses can be minimized by introducing intervention measures using the three classical strategies of education, engineering, and enforcement, which helped earlier to decrease the rates of MVCs in most developed countries [15]. However, these measures were developed based on crash experience in those countries, so they may not be fully applicable in KSA due to differences in the road network, environment, and road user characteristics.

Such specific intervention measures for any given country can only be successfully developed and implemented if the state of traffic safety in that country is well analyzed and understood. This study aims to investigate, collate, and analyze what is known about the state of traffic safety in KSA from official reports and the published peer-reviewed literature over the last 50 years. It is believed that such a comprehensive review and analysis would help in better comprehending the current road safety situation in the country and developing effective strategies to improve it.

2. MATERIALS AND METHODS

This study relied on a systematic review of relevant publications. Specifically, it counted on two major sources of information. The first source was based on an extensive review of the scientific literature on traffic safety in KSA according mainly to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. Published articles were included in the current study if they satisfied the following three conditions:

(1) published in peer-reviewed indexed journals,

(2) published in English or Arabic, and

(3) directly related to traffic safety in Saudi Arabia.

Studies that did not meet all the above three criteria were excluded. Six electronic databases (namely ScienceDirect, MEDLINE, ProQuest, PubMed, Google Scholar, and SafetyLit) were searched for this purpose. A list of references from retrieved papers was also searched for additional studies. Search keywords included Saudi Arabia and traffic safety, traffic crashes, traffic accidents or transportation safety. An initial screening was done by the authors to put together all potential studies relying on the title and abstract of each study. These studies were then filtered further after reviewing the full contents of the paper and removing duplications. No ethical approval was required as the review was based on published reports and manuscripts.

The second source was various official reports published by local and international organizations that were directly associated with the issues of road safety and the consequences of road crashes in KSA. These were either searched for and downloaded from the internet or requested and obtained in printed forms. A retrospective analysis was conducted on secondary data obtained from official reports on MVCs and MVC-related injuries and deaths in all thirteen districts of KSA from 1970 to 2019.

Except for very minor MVCs, like body scratches (estimated to constitute 30% of all MVCs by GTZ [10]), virtually all tangible MVCs are included in annual statistical reports of the GDT, MoI, SRCS and MoH. This assertion for crash reporting is claimed by traffic police in the country and achieved by enforcing a law that requires all vehicle repair establishments not to attend to any vehicle involved in a crash unless a police crash report is produced. Otherwise, severe penalties are issued for both drivers and establishments who violate this measure. This measure is believed to help in reducing underreporting of MVC-related injuries and fatalities and illegal alterations to motor vehicles to a minimum [7].

It should be noted here that in KSA, human losses due to MVCs are defined to include all road traffic-related crashes that result in injury or death to road users: drivers, passengers, cyclists, and motorcyclists or pedestrians. MVC injuries are defined to include all traffic-related non-fatal injuries, while MVC fatalities are defined as those who die at the crash scene or while being transported to the hospital [7]. If the number of people who die after being admitted to hospital due to road crashes is added, this number of fatalities will significantly increase [2, 17].

Major contributing factors to MVCs in KSA were analyzed by investigating speeding, careless driving, personal factors (*e.g.*, fatigue, driving under the effect of medicines, *etc.*), and vehicle and environmental conditions. Details of the place of death and the cost burden of MVCs were analyzed based on the ArRiyadh Strategic Traffic Safety Study conducted by ADA [18].

Population denominator data for the periods of 1970 to 2019 were obtained from the Annual Statistical Book of the

General Authority for Statistics [5], and the General Census of Population and Housing (CDSI) for the years of 1974, 1992, 2004, and 2010. In particular, population characteristics of the Riyadh area were obtained from demographic studies published by ADA. Networks of paved and gravel roads data were collected from MoT annual reports, while the number of annual registered vehicles in KSA and their technical faults were obtained from GDT and MVPI reports.

Annual crude rates of the MVCs, MVC deaths and injuries per 1000 crashes (*i.e.*, the ratio of fatalities and injuries to crashes), per 100,000 population (ratio of fatalities and injuries to 100,000 population), and per 10,000 registered motor vehicles (ratio of injuries and fatalities to 10,000 registered vehicles) were calculated to predict secular trends in factors shaping the MVC problem in the country. The ongoing risk of death and injury due to MVCs was also assessed using odds ratio analysis, which is commonly used in the analysis of crash severity data and relative risk [19]. Taking 1970 as the reference year, the odds ratio of fatalities among crash victims (injuries + fatalities) with 95% confidence intervals was computed for the period from 1970 to 2019 based on the work of Al-Shammari [20].

MVC rates in KSA were compared to international rates based on fatalities per capita (F/P), fatalities per 10,000 vehicles (F/V), and fatalities per one billion vehicle kilometers (F/VK). The overall mileage travelled by vehicles was assessed based on sampling models of GTZ [10] and Al-Shammari [20]. Data for comparison were obtained from international road crash databases, such as the International Road Traffic and Accident Database (IRTAD), Organization for Economic Co-operation and Development (OECD) reports, World Health Organization (WHO) statistics, and the annual world road statistic report of the International Road Federation (IRF) as well as from United Nations (UN) reports. All statistical analyses were performed using SPSS software (Ver. 24, SPSS, Inc, Chicago, IL, USA). Graphs and tables were produced using Microsoft Excel 2010 and OriginPro release 2017 SR2.

3. RESULTS

This strategic review study on motor vehicle crashes in KSA over the last fifty years included a total of 62 published peer-reviewed articles on traffic safety in Saudi Arabia on top of official national and international reports. It embraces four major findings. They include 1) historical growth and depth of the MVCs problem, 2) contributing factors to road crashes, 3) road crash characteristics, and 4) trends and losses due to MVCs in KSA based on official reports and the literature. Details on the above four findings are concisely presented in the following sub-sections.

3.1. Historical Growth and Depth of the MVCs Problem

Historical data between 1970 and 2019 on the MVCs were collated from annual reports produced by GDT, MoH and GASTAT [5, 7, 21]. Data on the population, number of registered vehicles, the total length of the road network, and the number of crashes and resulting injuries and deaths are presented in Table **1**.

Table 1. Vital statistics related to MVCs in Saudi Arabia between 1970 and 2019.

Year	Population (1000)	Registered Vehicles (1000)	Roads		MVCs		
			Paved	Gravel	Crashes	Deaths	Injuries
1970	5,745	145	8,334	3,487	9,123	570	5,483
1971	6,071	180	8,888	4,174	13,314	834	6,530
1972	6,323	243	9,244	4,963	22,656	1,058	7,901
1973	6,587	355	9,852	5,743	25,499	1,154	8,771
1974	7,009	514	10,801	6,770	31,801	1,594	10,532
1975	7,331	774	12,005	8,510	45,242	1,975	11,606
1976	7,670	1,113	13,817	11,193	50,670	2,032	11,413
1977	8,028	1,433	15,617	13,307	62,095	2,378	14,824
1978	8,406	1,723	17,646	16,948	61,568	2,871	16,832
1979	8,806	2,069	19,227	20,119	70,155	2,731	16,218
1980	9,229	2,468	20,474	24,186	65,503	2,427	15,872
1981	9,677	3,019	21,201	28,978	72,350	2,953	18,616
1982	10,152	3,569	21,841	33,310	79,193	3,499	21,475
1983	10,656	3,920	23,146	38,644	91,058	3,338	22,850
1984	11,191	4,144	24,455	46,836	80,765	3,277	22,630
1985	11,759	4,281	25,682	52,226	72,528	2,703	22,602
1986	12,363	4,428	26,377	57,502	73,335	2,814	23,723
1987	13,006	4,574	26,982	61,500	75,921	2,585	23,059
1988	13,692	4,768	27,808	63,905	85,071	2,647	23,278
1989	14,422	4,950	28,660	66,403	88,424	2,697	23,526
1990	15,202	5,117	29,537	69,000	87,248	3,232	25,516
1991	16,035	5,329	30,442	71,698	83,645	3,495	27,385
1992	16,948	5,588	31,374	74,501	82,386	5,982	34,441

(Table 1) contd.....

Year	Population (1000)	Registered Vehicles (1000)	Roads		MVCs		
			Paved	Gravel	Crashes	Deaths	Injuries
1993	17,366	5,862	32,335	77,414	121,654	5,883	35,884
1994	17,794	6,111	33,326	80,441	124,782	6,358	36,025
1995	18,232	6,334	34,346	83,586	174,738	3,123	26,115
1996	18,681	6,580	35,399	86,854	147,776	3,131	25,078
1997	19,141	7,046	36,483	90,250	174,214	3,474	28,144
1998	19,613	7,554	37,601	93,779	289,788	4,290	31,059
1999	20,096	8,049	38,753	97,446	296,013	4,848	32,361
2000	20,591	8,467	40,202	101,256	308,249	4,419	28,998
2001	21,098	9,009	41,468	105,215	330,322	3,913	28,379
2002	21,618	9,485	42,616	109,329	247,593	4,161	28,372
2003	22,151	9,947	43,120	113,604	281,885	4,293	30,439
2004	22,674	10,386	44,276	115,046	311,094	5,168	34,811
2005	23,256	10,928	44,986	118,567	314,857	5,982	34,441
2006	23,829	11,515	47,699	121,110	305,426	5,883	35,884
2007	23,981	12,121	52,302	125,441	458,880	6,358	36,025
2008	25,790	12,786	53,947	127,619	485,931	6,458	36,489
2009	26,660	13,447	54,974	130,736	484,805	6,142	34,605
2010	27,560	14,145	58,036	132,585	498,203	6,596	38,595
2011	28,570	14,842	59,143	136,831	544,179	7,153	39,160
2012	29,200	15,626	60,336	138,846	589,258	7,638	41,086
2013	29,990	16,601	61,376	140,870	526,429	7,661	37,530
2014	30,770	17,523	62,735	142,464	478,450	7,486	35,843
2015	31,520	18,554	64,412	144,152	518,795	8,063	36,302
2016	31,740	19,511	64,632	145,132	533,380	9,031	38,120
2017	32,552	20,906	65,964	146,146	460,488	7,489	33,199
2018	33,413	22,324	67,027	147,227	352,464	6,025	30,217
2019	34,218	22,959	68,151	148,344	287,781	5,754	32,910

Based on historical data presented in Table **1**, a retrospective analysis was conducted to assess secular trends related to the MVC problem in KSA. Annual crude rates of the MVCs, as well as MVC deaths and injuries per 100,000 population and 10,000 registered motor vehicles, were calculated. Rates of injury and death per 1,000 MVCs were also calculated to estimate the risk of injury or death in MVCs.

The Saudi population had grown rapidly at an annual average rate of 3.78% between 1970 and 2019 [5]. As a result, the number of registered motor vehicles has also increased at an average annual rate of 11.24% during the 1970s and 5 to 8% between 1980 and 2019, which reached close to 18 million. Such a fast growth in the number of registered vehicles indicates that motor vehicle ownership appears to be very high in the country as compared to others [7]. Similarly, the total lengths of paved and gravel roads also have significantly increased by nearly 8 folds (8,500 to 64,632 km) and 42 folds (3,487 to 145,132 km), respectively [8].

Based on the official statistics given in Table **1**, annual percent increases and percent changes were computed and plotted to analyze trends in injury, fatality and crash rate indicators due to MVCs during the fifty years between 1970 to 2019. Fig. (**1**) illustrates the annual trend in MVCs and resulting fatalities and injuries during that period. Fig. (**2**) shows the trends in injury, fatality and crash rates per person and per vehicle during the same period. As can be seen clearly in Figs. (**1** and **2**), there has been an alarming increase in the MVC problem in KSA over the last 50 years. Fig. (**2**) also clearly indicates that there is a trend in fatality and injury rates per vehicle to drop and per person to increase over the same period. Overall, the fatality rate per person has increased by 287%, while the fatality rate per vehicle has dropped by 12% during that period.

It is clear from Figs. (**1** and **2**) that all the devoted effort to tackle the MVC problem only succeeded in stabilizing the size or at least minimizing the growth of the problem. Thus, it is recommended that authorities and NGOs urgently develop various innovative and sustainable initiatives, some of which have been presented throughout this paper, to tackle this issue in a more vigorous way.

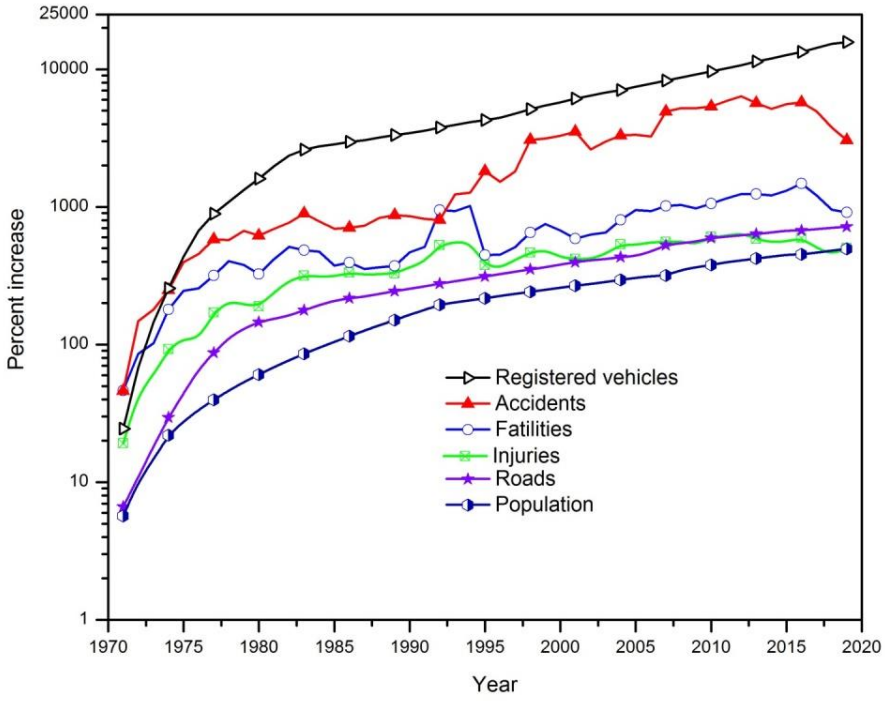

Fig. (1). Trends in MVCs and resulting fatalities and injuries (1970-2019).

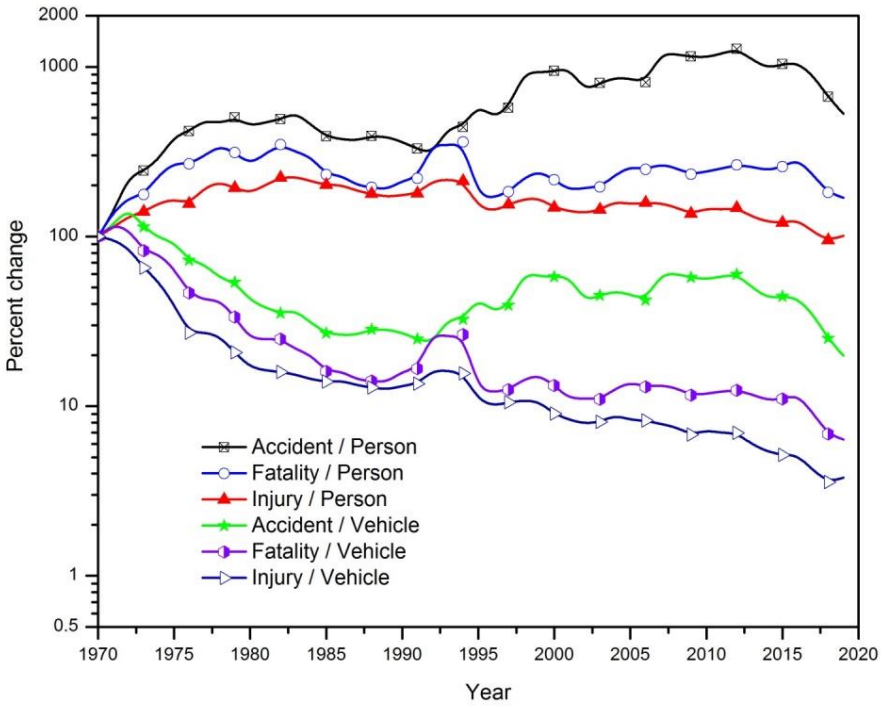

Fig. (2). Trends in injury, fatality and crash rates per person and per vehicle (1970-2019).

3.2. ContributIng Factors To Road Crashes

3.2.1. Causes Of Road Crashes

Most researchers agree that attempting to pinpoint a single cause for a motor vehicle crash is not usually realistic. Nevertheless, researchers and road traffic authorities tend to concentrate on a single factor that can be seen as the main contributor to the crash for legal, research and other purposes [1, 22]. DeNicola *et al*. [23] studied the causes of MVCs in KSA over eight years (between 2004 and 2011). The authors found that the main causes of MVCs in KSA are as follows:

(1) Speeding: 35.69%

(2) Improper turning: 8.43%

(3) Improper passing: 8.01%

(4) Traffic signal violations: 7.88%

(5) Improper stopping: 7.81%

(6) Others (including using electronic devices, tailgating, stunting, changing lanes unnecessarily, *etc*.): 32.17%

Numerous other studies have also demonstrated that 80 to 90% of MVCs could be attributed to the behavior of road users [6, 24 - 33]. Almost all of these studies have agreed that behaviors, like exceeding speed limits, careless driving, unwillingness to wear seat belts, crossing red lights, and ignoring traffic rules and regulations, lead to high rates of traffic crashes and enormous human and financial losses in KSA. Although the crash rate due to the leading cause of MVCs, which is excessive speeding, has dropped in recent years, this rate is still alarmingly high when compared to other countries, like the USA, as the rate in KSA is 2.38 times that of USA [7, 34].

3.2.2. DemoGraphic Factors

Researchers also have investigated the effects of gender and age on risky driving behaviors. Keeping in mind that women were prohibited from driving until 2018, research findings indicate that male younger drivers and expatriate drivers are consistently overrepresented in causing traffic collisions. Male younger drivers are significantly more likely to commit driving offenses than other groups of drivers. Besides this, the ever-increasing dependency on motor vehicles for transportation, lack of reliable public transport system, and the very large area of the country have created great opportunities for expatriate drivers to work in KSA [25, 35]. Those drivers were found to be responsible for about 40% of the MVCs in KSA [36], although they constitute one-third of the population [37]. This was mainly attributed to their coming from countries with high collision rates and aggressive driving behaviors [38] or from countries where right-hand driving is practiced, a situation which might be confusing for them since KSA has a left-hand driving system in place [39].

Another issue to be considered as a demographic factor is a driver's age. The median age of the Saudi population is 26.7 years. This indicates that the drivers' population is skewed toward a younger age range that is more likely to be involved in risky driving behaviors [23]. It is reported that teenagers are more susceptible to ignoring traffic signals in KSA, where more than 2,000 teenage drivers were caught running red lights in one year, possibly due to their unwillingness to yield to other drivers irrespective of the circumstances [33, 40].

3.2.3. Drivers' Behavior

The behavior of drivers is one of the crucial parameters to be considered in analyzing and understanding the causes of MVCs [33, 41 - 43]. To understand the behavior of drivers, Al-Khaldi [44] assessed the knowledge, attitude and practices related to driving of male students from the College of Health Sciences in Abha, Saudi Arabia.

Results revealed that more than 50% of the students were involved in crashes, with 22% of them getting injured and 13% being admitted to hospital. Results also disclosed that more than three-quarters of them had moderate to high knowledge of traffic regulations, and more than 90% believed in the importance of wearing seat belts. Most of the responding students also indicated that they had problems with the use of seat belts, including forgetfulness and anxiety.

In another study by Aba Hussein and El Zobeir [45], a sample of drivers from Qateef, Dammam, Al-Khobar and Jubail cities on the Eastern coast of Saudi Arabia were randomly selected to assess their knowledge and behavior in terms of traffic regulations and performance on the road. Results showed that 52% of the participants were previously involved in MVCs, 75% reported wearing seat belts, and 60% used mobile phones while driving. The authors concluded that knowledge of traffic regulations and driving risks of drivers did not match their behaviors.

Finally, it is worth mentioning here since alcohol consumption is forbidden in KSA, drink driving is not a common cause of road traffic collisions in this country, unlike in other countries.

3.2.4. Using Electronic Devices While Driving

According to the World Statistics Pocketbook issued by the United Nations [46], Saudi Arabia has 176.6 mobile-cellular subscriptions per 100 inhabitants. This is considered one of the highest rates in the world. This means that almost all drivers can access a mobile phone while driving a motor vehicle. There are strong indications that mobile phone use while driving is a contributing factor to road crashes in Saudi Arabia [33, 36].

Gharaibeh and Abdo [47] examined the knowledge of traffic safety issues and compliance among high school and university students. The authors found that 85% of participating students used their mobile phones while driving. Another study by Uchechukwu *et al*. [48] found that making or receiving phone calls while driving led to a seven times greater risk of being injured in traffic crashes among drivers in KSA than those who did not.

3.2.5. Seatbelt Wearing Rates

One of the major contributors to increasing the severity of any MVC is the non-use of protective devices, like seat belts [49]. It is well documented in the literature that failure to wear

seat belts is a major risk factor for all passengers in moving motor vehicles because they are effective in reducing the risk of injury in crashes [3, 31, 43, 50, 51]. Head, neck, cervical and spine regions are most frequently and seriously injured body areas from frontal collisions to occupants unrestrained by seat belts [2.52].

Wearing seat belts was made compulsory for drivers and front-seat passengers in Saudi Arabia on December 5th, 2000 [2]. Before that date, the wearing rate of seat belts was about 2% [53 - 55]. Moreover, children of less than six years of age were found to be exposed to higher risk during vehicle collisions than other age groups in Saudi Arabia, where this group constituted 7.2% of fatalities and 13% of injuries [56].

Official statistics also showed that there had been 4,848 fatalities per year before introducing the seat belt law in 2000, and these had been reduced by about 500 per year (i.e., around 20%) in each of the following two years. The number of injuries also was reduced by about 10% in the first year after enactment [57]. After enacting the seat belt law, the initial public awareness campaigns were accompanied by strict enforcement by traffic police. Bendak [2] recorded a significant increase in seat belt wearing rates from around 2% to more than 60% for drivers and from close to 0% to about 23% for front-seat passengers in the first few months after enacting the seat belt enforcement law in KSA. This led to a significant decrease in the number of head, spinal, pelvis and bleeding injuries due to MVCs. Nevertheless, in a follow-up study by Bendak [58], it was found that wearing rates dropped to 28% for drivers and 15% for front-seat passengers in the following years, mainly caused by less stringent law enforcement. Results of the same study also indicated that self-reported seat belt wearing rates by drivers did not match observed wearing rates. This was reflected through the much lower actual wearing rates than self-reported ones. This mismatch between beliefs and deeds was also reported by Al-Turky *et al*. [54], who found that 88% of drivers believed in the importance of wearing seat belts although only less than 3% of them wore them.

3.3. Road Crash Characteristics

To improve road safety, it is imperative to study and assess road crash characteristics. In this sub-section, the main road crash characteristics stated in official reports and the scientific literature are presented.

3.3.1. MVC types and body injuries

Al-Shammari [20] assessed the types of vehicle collisions that lead to deaths or injuries in Saudi Arabia. The author found that frontal (56%) and side collisions (27%) were the most frequently recorded types of all traffic crashes, leading to deaths or injuries. Other types of collisions (like rear-end collisions and rollovers) were responsible for causing the remaining 17% of deaths or injuries due to MVCs. The author also assessed injured body regions in MVC victims in KSA, and found that the head, thorax, arms and spine are the most injured parts due to MVCs. Finally, the author reported that 52% of the victims died at the crash scene, 5% died while being transported to the hospital, and 43% died after being admitted to the hospital.

3.3.2. Pedestrian crashes

More than one-quarter of severe road crashes in KSA involve pedestrians. This incurs a huge human and financial cost to the KSA society [59]. A detailed study by Al-Ghamdi [60] involving the evaluation of 638 pedestrian-vehicle crash cases in Riyadh found that nearly 80% of all severely injured pedestrians experienced multiple injuries and that 50% of them had head, spine and trunk injuries. The same study also revealed that 42% of all pedestrian victims were aged 15 years or younger, which made this group of pedestrians the most vulnerable to pedestrian crashes.

3.3.3. Camel collisions

A worldwide important traffic issue is the growing number of collisions between animals and motor vehicles. One of the most common large animals involved in such collisions is camels in KSA [61 - 65]. A wide range of solutions were implemented in different countries to try to resolve this issue, but neither unique solutions nor consistent results have been found [61, 62, 64, 65].

Colliding with large animals produces a distinct pattern of injuries than other MVCs. In large animal collisions, there is usually a higher frequency of injuries to the victim's head, neck, and upper torso area [65, 66]. More than 700,000 camels graze freely in KSA [67]. Recent official crash statistics show that more than six hundred camel-vehicle collisions (CVCs) occur annually in KSA [7]. MoT has applied several infrastructural measures over the past 30 years to prevent animal-vehicle collisions, including the construction of highway fencings and overpasses for camels. Consequently, the number of such collisions has dropped significantly, but this type of collision is still occurring. Because each camel weighs up to 726 kg, any camel-motor vehicle collision is expected to yield catastrophic consequences to the vehicles involved and their passengers. Therefore, more aggressive mitigation measures should be implemented to prevent CVCs [45, 65, 68].

3.4. Trends And Losses In Traffic Crashes

3.4.1. Risk of MVCs

A historical trend for the crash severity level was also assessed by computing an annual odds ratio (OD) of crashes between 1970 and 2019. Fig. (**3**) demonstrates this trend with upper and lower limits and a 95% confidence interval while taking the 1970 MVC figure as a base point. The trend shown in Fig. (**3**) identifies that no improvement in the odds ratio of crash severity has been recorded in KSA between 1970 and 2019, except for a short period between 1985 and 1990. It should also be noted that the OD of crashes has increased significantly since 2010.

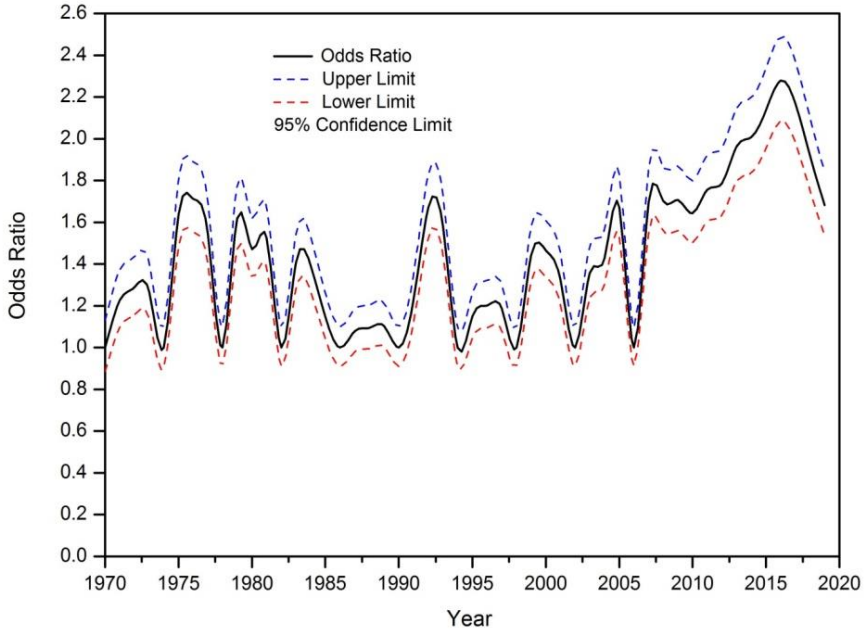

Fig. (3). Odds ratio of crash severity (1970-2019).

3.4.2. Human Losses Due to Road Crashes

For a better understanding of the extent of human losses in KSA, Barrimah *et al*. [69] incorporated health registration data on deaths due to traffic crashes. They showed that death rates due to traffic crashes recorded in the MoH registration records were significantly higher (sometimes more than double) than the police-reported ones. It should be noted here that road crashes cause up to 4.7% of all mortalities in Saudi Arabia, while they cause less than 1.7% in many developed countries, like Australia, the UK, and the US [1, 9, 38, 69].

3.4.3. Economic Losses Due to Road Crashes

In addition to human losses, road traffic crashes cause enormous economic losses. No comprehensive and accurate study has been conducted to determine economic losses due to traffic crashes in Saudi Arabia. All previous studies that tried to estimate economic losses due to MVCs in KSA were based on models used in developed countries (like the UK and USA) [6, 10, 53, 70 - 72]. These estimates ranged between US$0.53 billion [71] and US$16 billion [72]. It is believed that such large discrepancies in the loss estimates are caused mainly by differences in the estimated average wages, medical costs, crash vehicle repair costs, and others.

A detailed study worth mentioning in this regard is the one done by ADA using the concept of a 'Gross Output.' This study found that road crashes in KSA cost approximately US$ 6.73 billion annually [18]. Costs have been calculated using resource costs with amounts added for 'Pain, Grief, and Suffering', followed by adding 'Human' costs assessed by what is known as 'Willingness to Pay' (WTP) approach.

3.4.4. PoSt-Impact Care of Road Vsictims in Saudi Arabia

Post-impact care is an essential topic for reducing the severity of injury consequences when a traffic crash occurs [73]. Post-impact care includes actions of the injured person at the crash scene, help by bystanders, access to emergency facilities, intervention provided by ambulance officers and paramedics at the scene or while being transported to the hospital, hospital trauma care and availability to rehabilitation services [74]. Post-impact care has shown some weaknesses in KSA. The coverage of emergency medical services and trauma care was found to be relatively weak and disorganized when compared to the corresponding services in developed countries with similar land size. Officially, transferring people with traffic-related injuries to hospitals in Saudi Arabia should be done by Saudi Red Crescent Society (SRCS) ambulances [75]. Nevertheless, it is reported that only 67% of road crash victims in KSA are transported to hospitals by ambulances, 25% by regular motor vehicles, and 8% by airlifting [50]. Moreover, it is stated that scarcity of trained staff and field paramedics, underserved medical facilities, and shortage of adequate equipment are the main contributing factors to the high mortalities and disabilities rates due to MVCs in KSA [77].

As also identified by Mulat *et al*. [78], there are significant discrepancies in estimating the number of fatalities at the crash scene as well as before and after being admitted to the hospital due to road crashes across Saudi Arabia. For example, Badawi *et al*. [79] reported that only 12% of all traffic-related deaths were reported in the Asir region before being admitted to hospital while Khawashki [80] stated that 64-70% in the Riyadh region died before being admitted.

Another study by Ali *et al*. [81] reported that 40% of traffic-related deaths were recorded during the first 24 hours

after the crash. Al-Ghamdi [82] found that out of 138 deaths from traffic crashes in the Riyadh area during the years of 1994-1996, 45% died within the first 24 hours after being admitted to hospital, and 95% died within 30 days after the crash. Al-Shammari *et al*. [50] showed that of the 1,800 fatally injured persons due to crashes in Riyadh during 2005, 63% died before being admitted to hospital. Their results also showed that 84% died in intensive care units within the first 24 hours after admission.

Although several factors play an important role in the outcome of any road crash-related injury, the above-mentioned pre- and post-hospital admission death rates are considered high when compared to developed countries [14, 33, 45, 83]. Specifically, the ambulance response time in the Riyadh region has been identified to be below the standards, which are commonly practiced in developed nations, like the UK and the USA [50, 56, 77]. All the studies that have investigated the direct and/or indirect performance of the emergency rescue system in Saudi Arabia concluded that there is an imperative need to improve the quality of this system [17, 50, 57, 77, 80, 81].

3.4.5. Medical Consequences of MVCs in Saudi Arabia

Upper and lower extremities represent the most common injuries (31-38%) due to MVCs in Saudi Arabia [6, 60, 71]. Although extremity injuries due to road crashes are generally not life-threatening, they constitute a major cause of disability. Out of all those who are injured annually due to road crashes in KSA, 6 to 7% of them are discharged with residual disabilities [7]. In 2005, it was reported that 627 people lost their extremities because of road crashes in the country [21]. Other studies showed that the most common disability due to MVCs in KSA is amputation of limbs - arms or legs [45, 71, 84, 85].

The average length of stay at the hospital in KSA is estimated to be 10 to 13 days [82, 84]. It was also reported that the total number of beds operated by 274 MoH hospitals around the country was 41,835 in 2015. One-third of these beds are occupied by patients injured in road crashes [21]. Specifically, MVCs were the direct cause of 73.6% of all hemiplegia, paraplegia, and tetraplegia cases in KSA [53]. Moreover, it was reported that head (22-35%) and spine (5-9%) were the most common fatal injuries among road crash victims, both of which usually require long stays in hospitals [71, 82, 84]. Such figures put a strain on the medical system and deprive the country of vital medical resources [85].

4. DISCUSSION

Road collisions are a prevailing issue in KSA and bring huge human and financial losses. This study reviewed overall trends of motor vehicle crashes and the state of traffic safety in KSA over the last fifty years by collating and analyzing relevant published papers and official reports. This study serves as the first known one to collate and highlight the causes and consequences of MVCs in KSA over 50 years while taking into consideration a multitude of factors that could be identified in the published literature and official published and unpublished documents.

Overall review results from this study identified some major problem areas. One of the most striking problem areas is the risky behavior of road users. Many of those users, especially younger ones, consistently violate road safety regulations. This is reflected through many drivers tending to drive above the speed limit and pedestrians crossing the road where they should not. It is also reflected in the low proportion of drivers and passengers who wear their seat belts.

Another striking finding is the high percentage of expatriates living in the country who do not adhere to traffic safety regulations. This may be attributed to the fact that most of those expatriates come from countries with poor traffic safety records and different languages and tend to accept high risk on the road. Another finding is the ever-increasing use of electronic devices by road users. This distracting behavior, like many other countries in the world, is leading to more MVCs. Other contributing factors to road safety problems include the very large land area of the country and the high number of camels grazing in the deserts. It should also be mentioned here that the lack of a centralized road crash database and the fragmented road safety services hinder the proper development of road safety policies and regulations.

CONCLUSION

Based on these findings and in order to improve overall traffic safety and transportation sustainability in KSA, there is an urgent need for change in safety behavior among road users to minimize the risk of MVCs and improve the state of traffic safety in KSA. Such behavioral changes can only be achieved by enhancing awareness of road users, introducing more stringent traffic regulations and tougher penalties, and bringing engineering solutions to the problems mentioned throughout this study.

Increasing trends with respect to crashes, fatalities, and injuries in recent years may be attributed to the increase in traffic volume and vehicle population and the saturation of the effects of previously implemented safety measures. This raises the need to develop and introduce new and more up-to-date safety measures appropriate for Saudi Arabia's situation. Since most people in KSA heavily rely on private motor vehicles for their transportation needs, authorities in KSA need to enhance the public transport system by introducing more alternatives to private vehicles, like trains and buses. Similarly, it is strongly recommended to enhance the existing driver licensing process as it seems not to be fully achieving its purpose in conveying the importance of safe behaviors to younger driver candidates, as also postulated by Lee and Al-Mansour [86]. At the same time, it is recommended to provide sustained educational programs on safety issues and proper driving behaviors, especially targeting young drivers. Such education programs should include not only behavioral controls but also hazard perception and defensive driving skills [86]. Similarly, it is recommended to make road safety messages mandatory on all television and radio channels in Saudi Arabia. Such measures are highly anticipated to positively modify behaviors of road users, a point that was also emphasized by Stead *et al*. [87].

Finally, there seems to be an urgent need to establish a centralized road crash database in the country to aid the development of road safety policies, regulations and

technological changes. Such a national database system should include detailed information on crash causes, victims, drivers, medical consequences, weather conditions, time, location, *etc*., to help both government agencies and researchers in their efforts to reduce MVCs and their detrimental effects on the country.

LIST OF ABBREVIATIONS

ADA	=	Arriyadh Development Authority
GDP	=	Gross Domestic Product
GDT	=	General Directorate of Traffic
GASTAT	=	General Authority for Statistics
CDSI	=	General Census of Population and Housing
GTZ	=	Deutsche Gesellschaft fuer Technische Zusammenarbeit
IRTAD	=	International Road Traffic and Accident Database
MCI	=	Ministry of Culture and Information
MOH	=	Ministry of Health
MOI	=	Ministry of Interior
MOT	=	Ministry of Transportation
MVC	=	Motor Vehicle Crashes
MVPI	=	Motor vehicle periodic inspection program
KSA	=	Kingdom of Saudi Arabia
OECD	=	Organization for Economic Co-operation and Development
PRISMA	=	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
OD	=	Odds Ratio
SRCS	=	Saudi Red Crescent Society
UN	=	United Nations
WHO	=	World Health Organization

AUTHORS' CONTRIBUTIONS

NS collected some of the data and wrote part of the initial draft of this manuscript. SB and IK collected the remaining data and wrote part of the initial draft. SB prepared the final draft.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available within the article.

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CONFLICT OF INTEREST

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