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A Bayesian network model for analysis of causes and consequences of accidents

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Abstract

Background: Accidents are chains of events that lead to identifiable injuries and illnesses. Among various traumas, traffic accidents have the highest mortality rate.

Objectives: The aim of this study was to examine history data for analysis of the causes and consequences of accidents in Kingdom of Saudi Arabia during 2016-2020.

Methods: To collect the necessary data, the researchers utilized the Saudi open data portal, named as the National e-Government Portal. The data on consequence, type, seasons, location, and gender were extracted from the database. To analyze the collected data, GeNIe academic software was employed to conduct Bayesian network analysis.

Results: In total, 106513 accidents occurred in the Kingdom of Saudi Arabia during 2016-2020. Among them, 40287 and 9492 cases had the consequences of injuries and deaths, respectively. Regarding a sensitivity analysis of accident types, the worst variations in accident consequences were related to accident types of collapse, drowning, and car accidents. Therefore, those could increase the probability of death consequence by 5%, 4%, and 3%, respectively. Regarding a sensitivity analysis of location, for west and east regions, the probability of death consequences decreased by 1%. Moreover, regarding a sensitivity analysis of the season, the probability of deaths decreased by 1% in the autumn season. Regarding a sensitivity analysis of gender, females could decrease the probability of deaths by 4%. Other factors could not make variation in the probability of deaths.

Conclusions: These findings show most important accident types associated with death consequences are collapse, drowning, and car accidents. The locations of the west and east of the kingdom of Saudi Arabia, the season of autumn, and the gender of females could also decrease the death consequences.

Keywords: Accidents, Analysis, Causes, Consequences, Bayesian network model.

Introduction

Accidents are chains of events that lead to identifiable injuries and illnesses. Accidents constitute one of the most basic epidemics of non-communicable diseases. Those are part of the costs that humans pay for the advancement and development of technology.[1,2] Accidents, as the second cause of disabilities, can lead to physical and mental disorders and even death. Every year, more than five million people in the world die due to injuries caused by accidents, and tens of millions of people go to emergency medical centers because of accidents, drowning, falls, violence, electrocution, bites, suicide, etc. Additionally, the remaining consequences of accidents in human life include costs related to medical and rehabilitation needs and psychological effects on people.[2,3]

Humans play a big role in the occurrence of accidents; for example, 80% of occupational accidents happen due to unsafe behaviors.[4] Important accidents can always happen next to us, which cause the loss of human lives and the occurrence of heartbreaking scenes. For example, the Longford process accident, the Philadelphia platform accident, and the Challenger space shuttle accident are tragic examples of important industrial accidents in the world.[5,6] According to the statistics of the International Labor Organization (ILO), an average of 317 million occupational accidents occur annually, of which 2.3 million people lose their lives. In fact, every 15 seconds, 153 workers have an accident and one accident leads to

death.[7]

Studies have shown that children and teenagers are one of the most vulnerable groups against the risk of accidents and unintentional accidents are one of the 15 first causes of death in the age group of 0 to 19 years. According to the UNICEF report in 2018, accidents are the main cause of 30% of deaths in this age group.[8,9]

Injuries caused by traffic accidents are a serious threat to public health and one of the most common accidents that endanger the lives of many people in the world every year.[10] According to the report of the World Health Organization (WHO), 1.35 million people worldwide die due to injuries caused by road accidents every year, and between 20 and 50 million people are injured. According to a study conducted in developing countries, 80% of deaths and 90% of disabilities are related to road accidents.[11,12] Among the various traumas, traffic accidents have the highest mortality rate. Also, traffic accidents are the most common cause of death in the age group of 1 to 44 years in the world.[10]

In each traumatic accident, several variables influence the mortality or injuries. Research shows that more than 68% of the injured people are men and 32% are women in car crashes.[13] A reason for car accidents in female drivers is panic reaction and inattention. Based on the report of Taylor et al., female drivers compared to men showed higher levels of anxiety and panic in driving.[14] In the categorization of the WHO, trauma victims are categorized into 4 age groups, including children (people less than 12 years old), youth (13 to 17 years old), adults (18 to 59 years old), and elderly (more than 60 years old). Crash trauma is common in youth and adulthood. Young drivers do not have sufficient driving experience to evaluate speed or distance.[15-18] Furthermore, 78% of traumas in individuals aged 60 years and older lead to death.[19-21]

Very high or very low temperatures, high humidity, high and low atmospheric pressure, and changes in wind speed can cause changes in the body's physiology.[22] In a study conducted in Poland among construction site workers, the results showed that the highest frequency rate of accidents was in summer.[22]

One of the important components of any control program is research and investigation of happened accidents. Research on accidents is a scientific category. Accident investigation includes collecting all the information and real interpretations on an accident along with analyzing the information to find the causes of the accident and write an accident report.

Objectives

This survey examines history data for analysis of causes and consequences of accidents in KSA in the period of 2016 to 2020 to build a Bayesian network (BN) and eventually train the data, to recommend an approach of data-driven BN-based for accident analysis.

Methods

This retrospective study was conducted in 2022 among people in the Kingdom of Saudi Arabia. The inclusion criteria for data selection consisted of having citizenship of Saudi Arabia, having experienced accidents in cities of the Kingdom of Saudi Arabia, and recording damages, injuries, and death due to accidents in the cities of the Kingdom of Saudi Arabia. Exclusion criteria also consisted of lack of complete information on the studied parameters of accidents, including type, season, location, gender, and consequence. All persons with study criteria were entered into the study.

Data collection

The Saudi open data portal, named as National e-government Portal, was used to obtain data. The official e-government program was launched a few years ago with the name of "YESSER" in 2005. The initial goal of YESSER, as an e-government initiative, was to build and encourage the employment of digital applications by the government. The execution of the program was in two phases.[23] In the beginning, the purpose of this program was to help the government provide appropriate services to the citizens. Thereafter, with the launch of Open Government Data initiatives in 2011, a new era of e-government began in the Kingdom of Saudi Arabia. Providing data from the national portal as well as the internet site of the Ministry of Economy was the perspective followed by the Kingdom of Saudi Arabia.[24] This portal permits you to access, download, and use the data of ministries and government agencies in the Kingdom of Saudi Arabia.[23] The data on consequences (damages and injuries and deaths), type (drowning, car accidents, collapses, falls, occupational accidents, trapped, search for lost persons, and others), season (spring, summer, autumn, and winter), location (Center, west, east, south, and north), and gender (male and female) were extracted from the database. Given that only these data were available in the accident records of people, those were used for data analysis.

Bayesian Network Modeling

Several techniques exist for examining the causes and consequences of accidents. Bayesian Networks (BNs),

which are probabilistic and graphical models, were introduced by Pearl.[25] In recent years, particularly over the past decade, Bayesian networks have emerged as one of the premier conceptual frameworks for representing and reasoning with uncertain knowledge. Bayesian networks apply probabilistic principles to facilitate learning and reasoning processes.[26] These networks graphically depict random variables along with their conditional dependencies. Bayesian networks can analyze an event that has occurred and estimate the probability of contributing factors.[27] Such analytical approaches can be used across various domains, including safety, healthcare, and decision support systems.

Statistical analysis

The statistical tests were carried out using Microsoft Excel. Descriptive statistics were computed. In this study, GeNIe academic software version 2.3 was used to analyze the Bayesian network. After drawing the BN graphical structure, a Conditional Probability Table (CPT) was obtained by the model with the Expectation-Maximization algorithm.[28] Then, delta p sensitivity analysis was applied to rank the parameters.[29] Finally, a 10-fold cross-validation analysis was exploited to examine the model's validity. The dataset was randomly divided into ten equal folds, nine folds (9 subsamples) were applied to train the Bayesian network model, and the remaining fold (1 subsample) was used to validate the model. A sensitivity analysis was also conducted to examine the effects of the variables.[30]

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki.

Results

In total, 106513 accidents occurred in the Kingdom of Saudi Arabia in 2016, 2017, 2018, and 2020. Among them, 40287 cases were with the consequences of damage and injuries and 9492 with the consequences of deaths. Table 1 represents the statistical distribution of studied parameters. Among types of accidents, the highest statistics was related to falls with 44.00 percent. Most accidents occurred in the summer season (28.00 percent), in the center region (32.00 percent), and in males (86.00 percent). Among the consequences, the statistics of deaths and injuries were 19.00 and 81.00 percent, respectively.

Tables 2 and 3 report the Conditional Probability Table (CPT) for the types and consequences of accidents, respectively.

Figure 1 depicts the relationship among the studied variables based on the Bayesian network model. Tables S1 and S2 also describe the sensitivity analyses of the factors on accident types and accident consequences, respectively, which are available in the appendices section.

Based on the results of sensitivity analysis of location, for the central cities, accident types with the highest and lowest importance were car accidents with an increase of 5 percent, and falls with a decrease of 8 percent. For western cities, accident types with the highest and lowest importance included car accidents with an increase of 9 percent, and drowning with a decrease of 1 percent. For eastern cities, accident types with the highest and lowest importance were identified as car accidents with an increase of 12 percent and occupational accidents with a decrease of 1 percent. In four southern cities, accident types with the highest and lowest importance were car accidents with an increase of 6 percent and trapped with a decrease of 6 percent. For northern cities, accident types with the highest and lowest importance were determined as car accidents with an increase of 16 percent and falls and trapping with a decrease of 9 percent, respectively.

Based on the results of sensitivity analysis of seasons, for the spring season, accident types with the greatest and smallest importance were drowning and others with an increase of 1 percent and occupational accidents and trapped with a decrease of 1 percent. For the summer season, accident types with the greatest and smallest importance included car accidents with an increase of 3 percent and falls and trapping with a decrease of 1 percent. For the autumn season, accident types with the greatest and smallest importance were determined as falls with an increase of 2 percent and car accidents with a decrease of percent, respectively. For the winter season, accident types with the greatest and smallest importance were identified as occupational accidents with an increase of 1 percent.

In a sensitivity analysis of accident types, the worst variations in accident consequences were related to accident types of collapse, drowning, and car accidents. So those could increase the probability of death consequence by 5, 4, and 3 percent, respectively. The best variations in accident consequences belonged to search for lost persons and other types, which could decrease the probability of death consequences by 7 and 6 percent, respectively.

In a sensitivity analysis of location, for west and east regions, the probability of death consequences decreased by 1 while for other regions, the probabilities of injuries and deaths did not change. In a sensitivity analysis of the season, the probability of deaths decreased by 1 percent in

the autumn season while this probability did not alter in other seasons. In a sensitivity analysis of gender, females could decrease the probability of deaths by 4 percent while the gender of males could not make a variation in this probability.

The validity of the Bayesian model was assessed by ROC analysis. As indicated in Figure 2, the area under the curve was equal to 0.680. The values of the sensitivity, specificity, and accuracy of the model were computed by 0.645, 0.690, and 0.702, respectively.

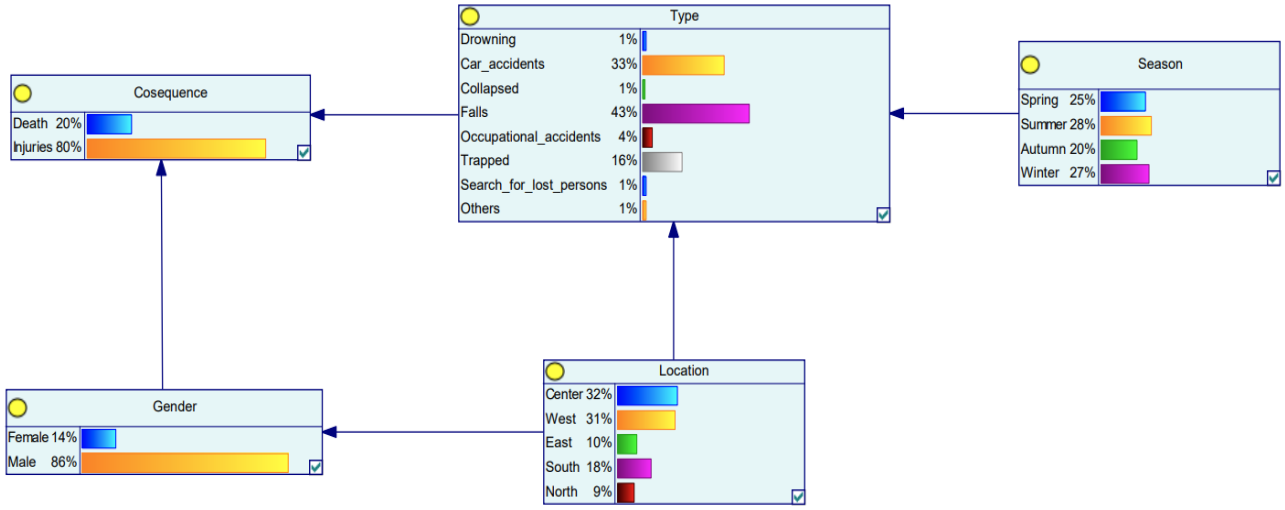

Figure 1. The relationship among the studied variables based on the Bayesian network model

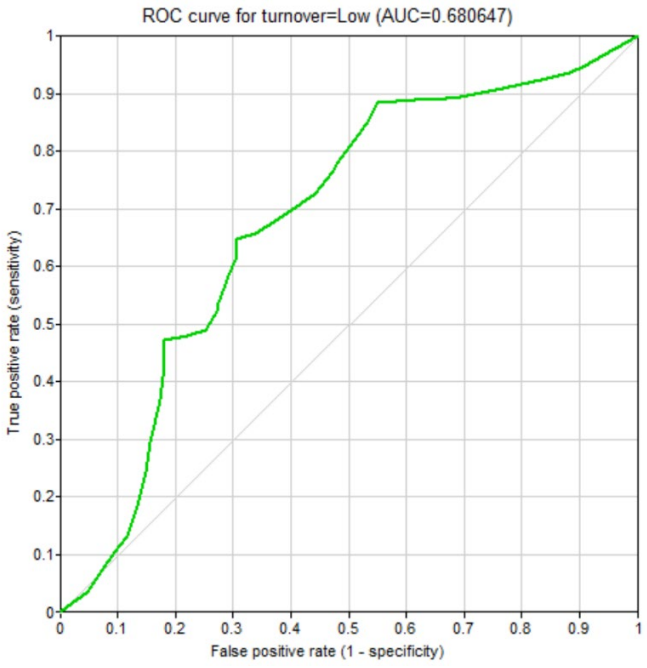

Figure 2. The ROC curve

Table 1. The statistical distribution of studied parameters

Parameter		Frequency(%)
Type	Drowning	498 (1)
	Car accidents	15431 (31)
	Collapsed	498 (1)
	Falls	21903 (44)
	Occupational accidents	1991 (4)
	Trapped	8462 (17)
	Search for lost persons	498 (1)
	Others	498 (1)
Season	Spring	12445 (25)
	Summer	13938 (28)
	Autumn	9956 (20)
	Winter	13440 (27)
Region	Center	16039 (32)
	West	15351 (31)
	East	5097 (10)
	South	9043 (18)
	North	4249 (9)
Gender	Male	43029 ()86
	Female	6750 (14)
Consequence	Injury	40287 (81)
	Death	9492 (19)

Table 2. The conditional probability table (CPT) for causes of the accidents

Item		Region				
		Center	West	East	South	North
Type	Drowning	0.01	0.0	0.01	0.02	0.02
	Car accidents	0.34	0.2	0.19	0.37	0.47
	Collapsing	0.01	0.01	0.01	0.01	0.01
	Falls	0.35	0.50	0.49	0.44	0.36
	Occupational accidents	0.06	0.05	0.04	0.03	0.05
	Trapping	0.18	0.17	0.22	0.12	0.08
	Search for lost persons	0.01	0.01	0.01	0.01	0.01
	Others	0.00	0.03	0.00	0.00	0.00

Table 3. The conditional probability table (CPT) for consequence of accidents

Item		Gender			
		Female		Male	
		Death	Injuries	Death	Injuries
Type	Drowning	0.20	0.80	0.25	0.75
	Car accidents	0.16	0.84	0.24	0.76
	Collapsing	0.23	0.77	0.25	0.75
	Falls	0.15	0.85	0.17	0.83
	Occupational accidents	0.15	0.85	0.23	0.77
	Trapping	0.19	0.81	0.20	0.80
	Search for lost persons	0.15	0.85	0.13	0.87
	Others	0.12	0.88	0.14	0.86

Discussion

In this survey, the causes, and consequences of accidents in KSA in the period of 2016 to 2020 were examined and analyzed by a Bayesian network model.

In total, 106513 accidents occurred in the Kingdom of Saudi Arabia from 2016 to 2020. Among them, 40287 cases were with the consequences of injuries and 9492 with the consequences of deaths.

Based on the results, among types of accidents, the highest statistics were related to falls (44%). Among the various causes of trauma, although falling from a height (ladder, scaffolding, tree, roof, etc.) is considered as one of the main causes of fatal accidents, the main focus of health managers is on road accidents, industrial accidents, and burn and the issue of falling has received less attention.[31,32] It is on this basis that the prevention of falling from a height is considered an attractive topic for experts. What makes the issue of identifying the causes of falls even more important is very low cost of preventing it in most cases, unlike road accidents, and it is based on education in most cases rather than the need to have special facilities. Based on the results of studies, most of the fall accidents happened due to domestic accidents and carelessness, which is noted as the cause of a quarter of the cases of falling from a height.[31,32] One of the main ways to prevent falling from a height in homes is to educate people and provide preventive solutions for such accidents. Because the majority of people do not know about the methods of observing safety points at home. The main reason for many unfortunate accidents at home is the lack of knowledge about safety points and the lack of education required in the society. Therefore, it is more important to educate everyone through the school system, the media, especially radio and television, as well as virtual space.[31-34] Also, a significant percentage of accidents related to falls are due to non-observance of occupational safety and industrial accidents, which are often preventable. Some studies have concluded that the roof and scaffolding are the main places of falls and most of the falls are caused by working on unsafe and non-standard scaffolding and slipping, lack of fall protection equipment, falling tools and waste materials, electrocution caused by contact with power transmission lines, Scaffold damage and destruction due to imbalance or overloading, and unsafe planking.[31-34] By examining the causes of falls from a height, training workers, the presence of personal protective equipment, the attention of the project manager to the issue of safety are the top factors in preventing falls,

which can be considered. According to some studies, the causes of falling from a height in the workplace have been categorized into three general groups including individual, managerial, and engineering causes.[31-34]

Based on the findings, most accidents occurred in the summer season (28%). It can be related to doing construction and industrial work in open areas, picking fruit, and doing housework such as washing the carpet and cleaning the door and wall of the house.[35,36]

Men were involved in most incidents (86%). Many researchers have mentioned notable differences in behavior and attitudes between the two sexes. The results of the studies have shown that the level of attention and caution in men is less than that of women. A common attribute is the willingness of men to take risks in conditions where the risk is not transparent.[37,38] Accordingly, control measures should be oriented towards ways that impact men's behavior and persuade them to increase caution under normal conditions. One of the ways to attain this goal can be through an effective information campaign via the media or other means.

Based on the model at the center cities with a distribution of 100%, the highest increase in probabilities was related to the type of car accidents. It may be because the central areas of the cities have more density and also the passageways of vehicles, which can be associated with a higher number of traffic accidents. This is consistent with the results of studies conducted by America and Mexico.[39-41]

Based on the model during the summer season with the distribution of 100%, the highest increase in probabilities was observed for car accidents. It can be due to the higher number of intercity trips in the summer season and the increase in the number of traffic in suburban areas.

Conclusions

In total, 106513 accidents occurred in the Kingdom of Saudi Arabia from 2016 to 2020. Among them, 40287 cases were with the consequences of damage and injuries and 9492 with the consequences of deaths. The highest statistics of accidents were related to falls. Most accidents occurred in the summer season and the center region and males were involved more in accidents. Identifying, evaluating, controlling, and training on risks and control methods is one of the most important tools to prevent such accidents. Education through public and social media can create a culture of safety. Moreover, strict rules for compliance with safety principles in construction, industrial, and agricultural workshops can prevent many accidents.

Acknowledgment

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Competing interests

The author declares that he has no competing interests.

Abbreviations

International Labor Organization: ILO;
Bayesian network: BN;
Conditional Probability Table: CPT;
World Health Organization: WHO.

Authors' contributions

The author read and approved the final manuscript. The author take responsibility for the integrity of the data and the accuracy of the data analysis.

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

By submitting this document, the author declares his consent for the final accepted version of the manuscript to be considered for publication.

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Table S1. Sensitivity analysis for location and season on accident types

Probability (percent)								Distribution (100 percent)								
								Location					Season			
Drowning	Car accidents	Collapsed	Falls	Occupational accidents	Trapped	Search for lost persons	Others	Center	West	East	South	North	Spring	Summer	Autumn	Winter
+ 1	+ 5	0	- 8	0	+ 3	0	0	✓								
- 1	+ 9	0	+ 8	0	+ 1	0	+ 1		✓							
0	+ 12	0	+ 7	- 1	+ 3	0	+ 1			✓						
+ 1	+ 6	0	0	+ 1	- 6	0	- 1				✓					
+ 1	+ 16	0	- 9	+ 2	- 9	0	0					✓				
+ 1	0	0	0	- 1	- 1	0	+ 1						✓			
+ 1	+ 3	0	- 1	+ 1	- 1	0	0							✓		
0	- 3	0	+ 2	- 1	+ 1	0	+ 1								✓	
0	0	0	0	+ 1	0	0	0									✓

Table S2. Sensitivity analysis for the factors on accident consequences

Probability (percent)		Distribution (100 percent)																				
		Type								Location					Season				Gender	
Damages and injuries	Deaths	Drowning	Car accidents	Collapsed	Falls	Occupational accidents	Trapped	Search for lost persons	Others	Center	West	East	South	North	Spring	Summer	Autumn	Winter	Female	Male
- 4	+ 4	✓																		
- 3	+ 3		✓																	
- 5	+ 5			✓																
+ 3	- 3				✓															
- 2	+ 2					✓														
0	0						✓													
+ 7	- 7							✓												
+ 6	- 6								✓											
0	0									✓										
+ 1	- 1										✓									
+ 1	- 1											✓								
0	0												✓							
0	0													✓						
0	0														✓					
0	0															✓				
+ 1	- 1																✓			
0	0																	✓		
+ 4	- 4																		✓	
0	0																			✓