Evaluation of Traffic Accidents in Jordan Using Accident Hazard Scale

Aslam Al-Omari [1], Mohammad Khasawneh [2] and Bader Ganam [3]

[1] Assistant Professor of Civil Engineering, Jordan University of Science and Technology, P.O. Box (3030), Irbid, Jordan. * Corresponding Author. E-Mail: aaalomari3@just.edu.jo
[2] Associate Professor of Civil Engineering, Jordan University of Science and Technology, P.O. Box (3030), Irbid, Jordan. E-Mail: mkhasawneh@just.edu.jo
3) Research Assistant, Civil Engineering Department, Jordan University of Science and Technology, P.O. Box (3030), Irbid, Jordan. E-Mail: bader.gannam88@gmail.com

ABSTRACT

Jordan suffers from traffic accidents because of resulting fatalities, injuries and both economic and social losses. This study aims at evaluating traffic accidents in Jordan, figuring out the important elements that may help in reducing traffic accidents' occurrence and providing decision-makers with information to help them in identifying risky regions which need remedial programs to reduce the impact of accidents. This objective is achieved using the Accident Hazard Scale (AHS) in different domains.

This AHS study concluded that the most dangerous Jordanian governorates were Al-Mafraq, Irbid, Amman and Al-Zarqa. The most hazardous months were July, August, September and June. Fridays and thursdays had the highest percentages ranging in the 75% – 100% zone level. The time period from 10 AM to 10 PM, specifically in evening peak hours (2 – 4 PM), was the most hazardous period according to the same AHS analysis.

KEYWORDS: Traffic accidents, Accident hazard scale (AHS), Accident index.

INTRODUCTION

On the 31st of August 1869, the world's first road death involving a motor vehicle took place. Irish scientist Mary Ward died when she fell out of her cousins' steam car and was run over by it (Offaly History, 2007). To show the importance of traffic accidents globally, the World Health Organization (WHO), in its global status report on road safety 2009, estimates that the majority of the world's fatalities on roads occur in low-income and middle-income countries (WHO, 2009). These countries have only 48% of the world's registered vehicles. This can be considered an important cause for these fatalities. At the same time, other causes can play important roles in increasing the percentage of these fatalities. Among these causes is the high percentage of pedestrians in these countries. The same report also predicts that road traffic injuries will rise to become the 5th leading cause of death by 2030 (WHO, 2009). The global economic cost of traffic accidents was estimated at $518 billion per year in 2003 (WHO, 2004; WHO, 2009) and $100 billion of this cost is spent in developing countries (WHO, 2004).

Jordan, like many other countries, suffers from traffic accidents in the form of both economic and social losses. Jordan is classified as a middle-income country, where traffic accidents are considered one of the major causes of death. Jordan loses approximately JD750 thousand per day (JD275 million per year) due to traffic

Received on 1/9/2017.
Accepted for Publication on 26/8/2018.

accidents (Jordan Traffic Institute, 2015).

According to Jordan Traffic Institute (JTI) in its last report (JTI, 2015), Jordan had 111,057 accidents, 16,139 injuries, 608 fatalities and JD275 million of financial cost in 2015. This cost is for the accidents that involved humans; thus property damage only (PDO) losses are not included in this figure. Traffic accidents have negative effects in the form of both economic and human losses for individuals and the society. Thus, the main objective of this study is evaluating traffic accidents in Jordan and figuring out the important elements that may help in reducing traffic accidents' occurrence.

Ismail (1988) presented an overview of traffic safety in Jordan. The study was conducted to give some statistics of accidents and to suggest solutions that may help in reducing traffic accidents in Jordan. The important statistics mentioned were more than 6,000 fatalities and more than 86,400 injuries in road accidents during the period from 1972 to 1988.

Al-Masaeid (2009) investigated the problem of pedestrians' involvement in traffic accidents. According to the results, pedestrian accidents constituted about 5% of the total accidents, but they made up about 34% of the total traffic fatalities and 26% of the total traffic injuries. Regarding drivers' involvement rates, the most dangerous drivers were young ones below 25 years. Their accidents increased between 1.6 and 2.5 times when compared with the overall averages of other ages.

Adeleke et al. (2013) showed the trend of highway accidents in Nigeria, using highway Accident Hazard Index (AHI). The accident rate indices were: accident rate per 100 million vehicle-miles, accident rate per 100,000 population, accident rate per 10,000 registered vehicles and accident rate per 1,000 miles of paved highway. The results of this study showed that Ebonyo, Kebbi and Borno were the highest hazard states in Nigeria during the period 1996-1998. Zamfara, Jigawa and Borno came first in the list in the period 2005-2007 regarding states that needed remedial programs in traffic safety. Identifying states classified as High Accident Locations (HALs) based on their Accident Hazard Index (AHI) helped determine states that mostly needed remedial programs to improve road safety.

DATA AND METHODOLOGY

This section presents a brief explanation on the data used and the methodology followed to accomplish this paper. A complete description of the data and methodology can be found in Ganam (2017).

Data Sources and Collection

The data used in this research was obtained from various sources and covered the period between 1981 and 2015. Characteristics of traffic accidents were obtained from analyzing the available data. The data was collected, tabulated and then analyzed. Most characteristics were obtained for the period between 1997 and 2015, including age of drivers, severity, speed limit, monthly distribution of accidents, accidents' distribution per governorate, among others. Authorities that were the sources of data are: Department of Statistics (DOS), Jordan Traffic Institute (JTI), Public Security Directorate (PSD), Central Traffic Department (CTD), Customs Department (CD), as well as other authorities concerned with traffic accidents.

Analytical Technique for Accident Hazard Scale (AHS)

This paper uses a technique which is based on applying a new simple tool that can determine the hazards of accidents at various levels. The objective here is to provide decision-makers with one figure that helps them in identifying risky regions which need remedial programs to reduce the impact of accidents. This objective is achieved through finding a scientific scale for hazards due to accidents by different domains, like governorates, months of the year, days of the week and hours of the day.

The items in each domain are ordered from the most dangerous one, with 100% on the hazard scale, to the one with the lowest percentage on the same scale. After completing this scale, the highest percentages (75% or more on the hazard scale) represent the most hazardous items which have the highest priority in the implemented remedial programs to reduce hazards.

This principle is very similar to the principle of locating stop stations on a new public transit route that goes through many districts, based on above and below averages regarding some characteristics of these districts.

The following equations were applied on data to obtain the Accident Hazard Scale (AHS):

$$H_{j,i} = (1 \times Av_j Acc._i) + (3 \times Av_j Inj._i) \quad (5 \times Av_j Fat._i) + (4.5 \times Av_j Sev._i) \tag{1}$$

$$T.H_{j,i} = \sum_{j=1}^{n}((1Av_j Acc._i) + (3Av_j Inj._i) + (5Av_j Fat._i) + (4.5Av_j Sev._i)) \tag{2}$$

$$A.H.S_i = \left(T.H_{j,i} \middle/ Max.\ T.H_{j,i} \right) \times 100 \tag{3}$$

where:

$H_{j,i}$: hazard points in the i^{th} item and j^{th} year;

$T.H_{j,i}$: total hazard points for a specified i^{th} item in all j^{th} years;

$A.H.S_i$: accident hazard scale in percentage for a specified item i;

$Av_j Acc._i$: point obtained due to number of accidents in i^{th} item averaged for year j;

$Av_j Inj._i$: point obtained due to injuries' number in i^{th} item averaged for year j;

$Av_j Fat._i$: point obtained due to fatalities' number in i^{th} item averaged for year j;

$Av_j Sev._i$: point obtained due to severity level in i^{th} item averaged for year j;

$Av_j Acc._i$, $Av_j Inj._i$, $Av_j Fat._i$ and $Av_j Sev._i$ are taken as 1 if above the average for year j and are taken 0 if below it;

1, 3, 5 and 4.5: typical weights (FHWA crash rate eq.) in severity of accidents for property damage only, injury, fatality and severity level, respectively.

The calculation of equations 1, 2 and 3 is shown below with description of each step implemented to achieve the objective of determining hazard scale for the different domains.

Procedure and Sample Calculation

The procedure that is used to find AHS and sample calculation are provided in this section. As previously mentioned, the objective of the scale is to find one figure that provides an overview of the safety situation related to accidents in various domains (governorates of Jordan, months of the year, days of the week and hours of the day). The procedure is summarized by the following steps:

Step 1: Preparing and tabulating numbers of accidents, injuries, fatalities and severity values for each domain.

Step 2: Calculating the average of each number for each year alone.

Step 3: Comparing each number with its yearly average. If it is greater than this average, it takes the value 1 in the points of the scale; otherwise, it takes 0.

Step 4: Multiplying the values by their corresponding weights; for accidents by 1, for injuries by 3, for fatalities by 5 and for severity by 4.5 and estimating their sum.

Step 5: Finding the sum of points in step 4 for a specific item (like Saturday in days' domain or Amman in governorates' domain) for all the years of the study period.

Step 6: Finding AHS in each domain as percentage estimated by dividing the total points of a specific item by the highest total points among all items.

To understand these steps, the following sample calculation is provided herein to find AHS in the governorates of Jordan.

Table 1 shows the numbers of items (i) and years (j) for each domain in the period that was covered. These numbers are used to determine the location of values in our data.

Table 1. Numbers of items and years in each domain

Domain	Governorate	Months	Days	Hours
No. of Items (i)	12	12	7	12
No. of Years (j)	19	19	10	10
Period Covered	1997 - 2015	1997 - 2015	2006 - 2015	2006 - 2015

Tables 2, 3 and 4 provide all AHS results related to governorates. Columns 2, 4, 6 and 8 in Table 2 represent step 1 concerning our data. The cells that are obtained by crossing the last row (average row) with columns 2, 4, 6 and 8 in the same table, represent step 2 that shows yearly averages for accidents, injuries, fatalities and severities.

For step 3, the average number of accidents in 1997 (j=1) was 3,250.4. The number of accidents was 4,007 in Al-Zarqa governorate (i= 3). Since 4,007 is greater than 3,250.4, Al-Zarqa governorate recorded one point (i.e., $Av_j Acc._i = Av_1 Acc._3 = 1$).

The $Av_j Acc._i$ values were then multiplied by the corresponding typical weight for accident property damage only (weight = 1) as shown in column 3 of Table 2 $(1 \times Av_1 Acc._3 = 1 \times 1 = 1)$. Similarly, Al-Zarqa governorate recorded 3, 5 and 0 points in injuries, fatalities, and severities, respectively. The sum of all points for Al-Zarqa governorate is 9. This number represents the hazard points in Al-Zarqa item during 1997 ($H_{1,3} = 9$).

This sum represents step 4 when we apply Eq. (1) mentioned above.

$$H_{1,3} = (1 \times Av_1 Acc._3) + (3 \times Av_1 Inj._3) + (5 \times Av_1 Fat._3) + (4.5 \times Av_1 Sev._3) = 9$$

Table 2. Hazard points for each governorate of Jordan according to data from 1997

Governorate	Acc.*	(A)**	Inj.*	(B)**	Fat.*	(C)**	Sev.*	(D)**	$H_{j,i}$
Amman	23585	1	6078	3	132	5	0.26	0	9
Irbid	3775	1	2539	3	87	5	0.70	0	9
Al-Zarqa	4007	1	2166	3	53	5	0.55	0	9
Al-Balqa	2100	0	1215	0	43	0	0.60	0	0
Al-Karak	799	0	695	0	46	0	0.93	4.5	4.5
Al-Mafraq	1511	0	1315	0	112	5	0.94	4.5	9.5
Ma'an	465	0	444	0	22	0	1.00	4.5	4.5
Al-Aqaba	841	0	401	0	37	0	0.52	0	0
Madaba	592	0	415	0	5	0	0.71	4.5	4.5
Al-Tafilah	260	0	179	0	8	0	0.72	4.5	4.5
Jerash	576	0	459	0	26	0	0.84	4.5	4.5
Ajloun	494	0	353	0	6	0	0.73	4.5	4.5
AVERAGE	*3250.4*	--	*1354.9*	--	*48.1*	--	*0.71*	--	--

* Acc.: accidents, Inj.: injuries, Fat.: fatalities and Sev.: severity.

** A: $(1 \times Av_j Acc._i)$, B: $(3 \times Av_j Inj._i)$, C: $(5 \times Av_j Fat._i)$ and D: $(4.5 \times Av_j Sev._i)$.

Step 4 was repeated for all items from i=1 (Amman) to i=12 (Ajloun) to find all governorates' hazard points during 1997 as shown in the last column of Table 2 and during other years as shown in Table 3. The results of step 5 are shown in the last column in Table 3 and are calculated by using Eq. (2) in the methodology.

The total hazard points are calculated by taking the sum of a specific item (like Al-Zarqa item with i=3) over all our period (from j=1 in 1997 to j=19 in 2015), which is denoted by ($T.H_{j,i}$); it is 162 points in our selected item represented by Al-Zarqa ($T.H_{13}$=162). This result for Al-Zarqa governorate and other governorates were calculated as shown in the last column in Table 3.

Table 3. Hazard points for each item in the governorates of Jordan for all years of the period and their total over these years

Governorate	$H_{j,i}$									$T.H_{j,i}$
	1997	1998	1999	2000	…	2012	2013	2014	2015	
Amman	9	9	9	9	…	9	9	9	9	171
Irbid	9	9	9	9	…	9	9	9	9	171.5
Al-Zarqa	9	9	9	9	…	9	8	8	9	162
Al-Balqa	0	0	0	5	…	5	5	0	0	29.5
Al-Karak	4.5	4.5	4.5	4.5	…	9.5	4.5	4.5	4.5	90.5
Al-Mafraq	9.5	9.5	12.5	12.5	…	4.5	0	9.5	0	183.5
Ma'an	4.5	4.5	4.5	4.5	…	4.5	4.5	4.5	4.5	90.5
Al-Aqaba	0	0	0	0	…	0	0	0	0	5
Madaba	4.5	0	0	0	…	0	0	0	0	4.5
Al-Tafilah	4.5	4.5	4.5	4.5	…	4.5	4.5	4.5	4.5	81
Jerash	4.5	4.5	4.5	4.5	…	4.5	4.5	4.5	4.5	67.5
Ajloun	4.5	0	0	0	…	4.5	4.5	4.5	0	36

The last step in the procedure was the calculation of AHS as percentage. In brief, the maximum points' value was 183.5 in Al-Mafraq item among all items and the selected item (Al-Zarqa) had 162 points. Therefore, to find the AHS for Al-Zarqa governorate, Eq. (3) was performed as follows:

$A.H.S_3 = \left(162/_{183.5}\right) \times 100 = 88.3\%$. This value for Al-Zarqa governorate and the values for the other Jordanian governorates are shown in Table 4.

Table 4. Accident hazard scale (AHS) for each governorate of Jordan over all years

Governorate	$T.H_{j,i}$	AHS_i (%)
Amman	171	93.2
Irbid	171.5	93.5
Al-Zarqa	162	88.3
Al-Balqa	29.5	16.1
Al-Karak	90.5	49.3
Al-Mafraq	183.5	100.0
Ma'an	90.5	49.3
Al-Aqaba	5	2.7
Madaba	4.5	2.5
Al-Tafilah	81	44.1
Jerash	67.5	36.8
Ajloun	36	19.6
Max.	*183.5*	

RESULTS AND DISCUSSION

Figure 1 shows the AHS results for the different Jordanian governorates. The AHS values were arranged in Figure 1 from the highest (most risky) governorate to the lowest (least risky) one.

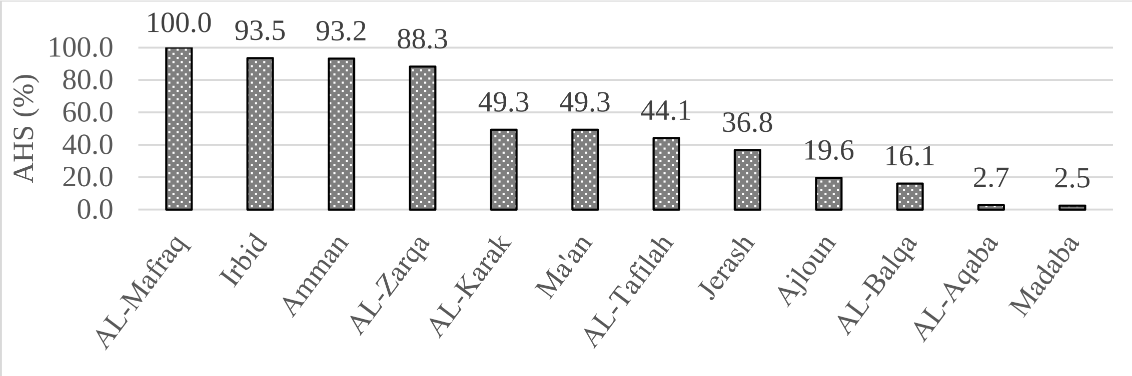

Figure (1): Accident hazard scale of Jordan's governorates over the period 1997-2015

The highest governorates of Jordan on this scale were Al-Mafraq, Irbid, Amman and Al-Zarqa in a descending order. Al-Mafraq came on the top of the scale, where a very high severity level was recorded during the study period and large points were recorded on our scale. This may be due to the fact that most international routes (Al-Azraq road to Saudi border, Jabber road to Syrian border and Rewashed road to Iraqi border) intersect in Al-Mafraq governorate. Thus, the highest numbers of injuries and fatalities occurred in this governorate.

Figures 2, 3 and 4 illustrate the AHS results for months of the year, days of the week and hours of the day, respectively.

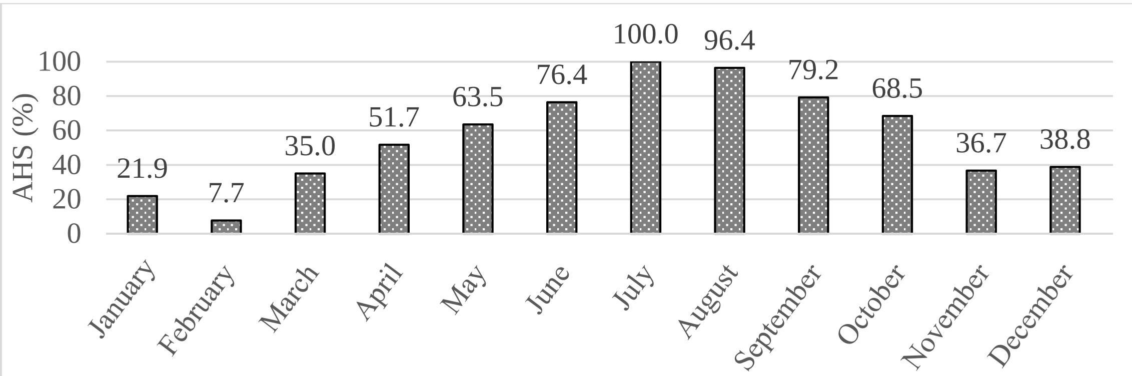

Figure (2): Accident hazard scale for the months of the year over the period 1997-2015

Regarding months of the year, as shown in Figure 2, the highest percentages of accident hazards were in July, August and September with 100%, 96.4% and 79.2%, respectively. In general, the summer months have higher risk regarding accidents than the winter months. Similar conclusions can be found in Al-Khateeb (2010).

These patterns can be interpreted by the fact that traffic flow during the summer season is greater than that in the winter season, as the number of visitors including expatriates with their own vehicles to Jordan in summer is much higher. This verifies what was found in Ismail (1988). Moreover, climatic factors (summer and winter) significantly influenced hazards of accidents in Jordan, as shown by our scale. For example, as a result of climatic factors, drivers will drive more cautiously in winter with lower speeds, which will result in lower risk and lower number of accidents.

Analysis of days of the week which is shown in

Figure 3 exhibits an unexpected behavior, where the percentages of weekend days in addition to Thursday's percentages were higher than those of work days. The same result was found in Al-Omari et al. (2013). Weekend days (Friday and Saturday) constitute about 171.4% of hazards out of the total percentage which is equal to 371%. This percentage is very high and approximately represents a half of the accident risks. This behavior can be attributed to several reasons. One reason is the higher possibility of high speeds because of lower traffic volumes during weekends. This obviously causes more severe accidents resulting in more casualties. Another reason is the higher number of recreational trips in the weekend. In these trips, driving is for long distances on rough and unfamiliar roads. Then, numbers of injuries and fatalities are expected to increase due to serious accidents that may take place which increase severity levels multiplied by 4.5 on the AHS.

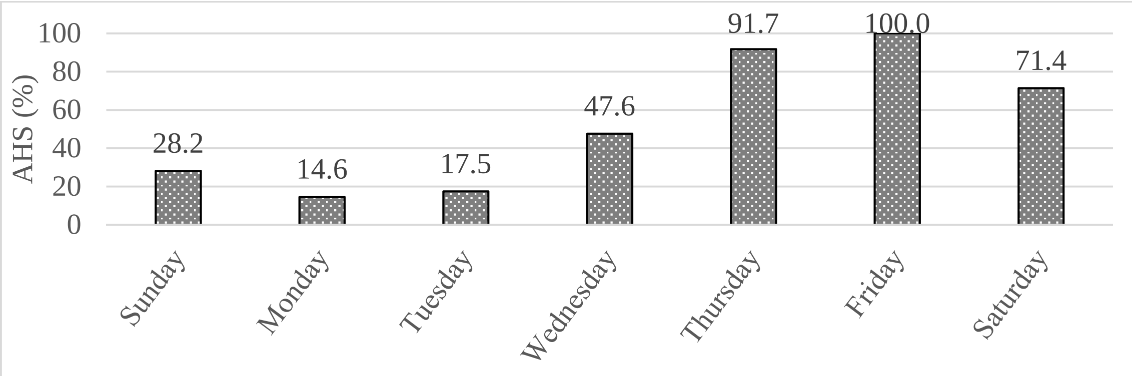

Figure (3): Accident hazard scale for days of the week over the period 2006-2015

The week starts with an AHS percentage of 28.2% on Sunday, which is slightly higher than for Monday and Tuesday. Then, the percentage of AHS increases towards the end of the week reaching the highest value on Friday. After that, it decreases on Saturday with 71.4% on AHS. Thursday came second among the highest percentages (91.7%). This is normal because the highest number of accidents occurred on this day.

Regarding hours of the day, as shown in Figure 4, the most five dangerous intervals according to AHS analysis are found to be (4-6 PM), (10-12 AM), (2-4 PM), (12-2 PM) and (6-8 PM) in a descending order. This finding is supported by Al-Omari et al. (2013). Generally, the 12-hour period (from 10 AM to 10 PM) represents the major hazards, which requires intensifying traffic controls at these times to reduce risks. Noticeably, the interval from 2 AM to 6 AM shows an unexpected increase in AHS percentages, which may be accounted for by the high number of injuries and fatalities caused despite the few number of accidents in the same interval.

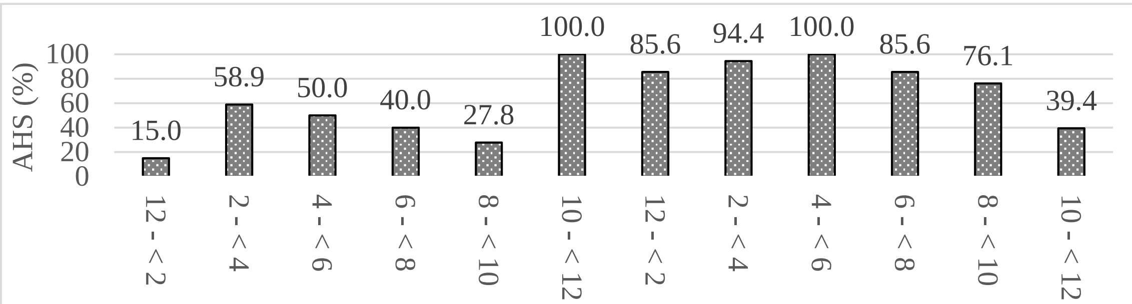

Figure (4): Accident hazard scale for hours of the day over the period 2006-2015

All the previous figures of AHS results shown above are summarized in one figure; Figure 5. This figure, which contains four AHS scales for different domains, is a very powerful tool presenting a good overview of accident situation for decision-makers to help them undertake remedial programs.

Figure 5 has been designed to divide the AHS scale for each domain into four risky levels. The first level is from 100% to 75%, including the most dangerous items. The second, third and forth levels come with ranges of 75% to 50%, 50% to 25% and 25% to 0%.

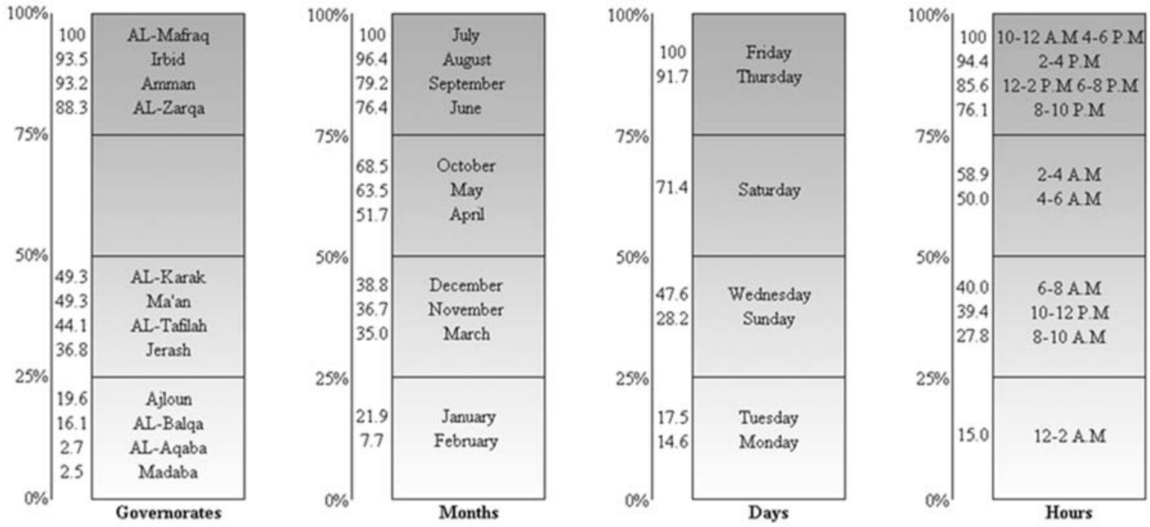

Figure (5): Accident hazard scales for all domains in one figure

Whenever these levels go down, the dangers of items will decrease and the priorities to implement remedial programs to fix their situations will decrease too. The power of Figure 5 and how decision-makers can utilize this figure will be illustrated in the following few steps. At first, the decision-maker must know that the priorities are taken into account according to the scientific scale of accident hazards for each item in each domain.

Secondly, the main objective is to reduce the risk of accidents according to the available capacities which will be directed to major items of the highest risk level (100% to 75%). Figure 5 can be used in accordance with a systematic procedure which is described in Ganam (2017).

CONCLUSIONS AND RECOMMENDATIONS

The AHS represented a simple tool that described priorities of remedial programs to fix accident problems. The main conclusions are as follows:

- Governorates with highest AHS values were Al-Mafraq, Irbid, Amman and Al-Zarqa.
- The most hazardous months according to AHS were July, August, September and June.
- Weekends had the highest percentages that are in the 75% to 100% zone level.
- Generally, the hours from 10 AM to 10 PM, specifically in evening peak hours (2-4 PM), represented the most hazardous hours according to the AHS analysis.

In light of the study findings, the researchers present the following recommendations:

- The current AHS analysis should be taken into account when decision-makers design remedial programs.
- To reduce the severity of accidents, speed control devices are to be installed on internal streets as well as on external streets.
- Severer penalties should be implemented in order to achieve the desired objectives represented in mitigating the effects of road accidents on the country's economy as well as on its people's lives.

REFERENCES

Adeleke, O., Salami, A., and Oyewo, S. (2013). "Trend of highway accidents in Nigeria using highway accident hazard index". International Journal of Engineering, 11 (3), 231-236.

Al-Khateeb, G. (2010). "Analysis of accident data and evaluation of leading causes for traffic accidents in Jordan". Jordan Journal of Civil Engineering, 4 (2), 76-94.

Al-Masaeid, H. (2009). "Traffic accidents in Jordan". Jordan Journal of Civil Engineering, 3 (4), 331-343.

Al-Omari, B., Ghuzlan K., and Hasan, H. (2013). "Traffic accident trends and characteristics in Jordan". Jordan Journal of Civil Engineering, 7 (1), 9-15.

Ganam, B. (2017). "Evaluation of traffic accidents in Jordan using time series analysis and other analytical techniques". M.Sc. Thesis, Jordan University of Science and Technology.

Ismail, I. (1988). "An overview of traffic safety in Jordan". Institute of Transportation Engineers, 58 (11), 43-46.

Jordan Traffic Institute (JTI). (2013). "Accident hazardous locations in Jordan". Ministry of Interior, Public Security Directorate, Amman, Jordan.

Jordan Traffic Institute (JTI). (2015). "Yearly report of traffic accidents in Jordan". Ministry of Interior, Public Security Directorate, Amman, Jordan.

Offaly Historical and Archaeological Society. (2007). "Mary Ward 1827-1869–famous Offaly people". (Created on 2 September 2007), 1827-1869, (Accessed on 18 November 2016).

World Health Organization (WHO). (2004). "World report on road traffic injury prevention; chapter 2: the global impact". Page 25. Accessed on 10 November 2016.

World Health Organization (WHO). (2009). "Road safety report: global status report on road safety; leading causes of death, 2004 and 2030 compared". Accessed on 18 November 2016, Page 9.