Analysis of increment of road traffic accidents in Libya: Case study city of Tripoli

S I A Ali 1*, F A A Elturki 1, S N Jibrel 2

1Civil Engineering Department, Near East University, Near East Boulevard, 99138 Nicosia, North Cyprus, Mersin 10, Turkey.
2Higher Institute of Science and Technology, Albrket, Ghat, Libya

*E-mail: shabarofking10@gmail.com

Abstract. Traffic and highway engineers working with law enforcement officials are constantly seeking for better methods to ensure safety for motorists and pedestrians. The planning process requires that engineers collect and maintain traffic safety data, identify the hazards location, conduct studies and establish project priorities. Unfortunately, in Libya, the increase in demand for private transportation in recent years, due to poor or lack of public transportation led to some traffic problems, especially in the capital (Tripoli). Also, the growth of private transportation has significant influences on the society regarding road traffic accidents (RTAs). This study investigates the most critical factors affecting RTAs in Tripoli, the capital city of Libya. Four main classifications were chosen to build the questionnaire, namely; human factors, road factors, vehicle factors, and environmental factors. Moreover, the data was collected from 400 respondents in the study area, and the relative importance index (RII) was used to rank the factors. The results show that human factors have the most significant impacts compared with other factors. Moreover, 84% of respondents considered the over speeding as the most affect cause factors of RTAs while 81% considered the disobedience to driving regulations as the second most influential factor in human factors. Besides, 74% of respondents considered poor brakes or brake failure factor has a high impact on the RTAs among the vehicle factors, while 79% classified poor or non-street lighting factors as one of the most effective factors on RTAs in road factors. The environmental factors have slight influences on RTAs.

1. Introduction

Road traffic accidents (RTAs) are considered as one of the main problems in the world. It was found that the RTAs were ranked as the 11th leading cause of death globally, where about 1.24 million people die each year as a result of road traffic crashes, and they were the primary cause of physical disability for drivers, passengers, and pedestrians in developing countries [1]. Growth in urbanization and an increase in the number of vehicles has led to traffic congestion in urban centres and subsequently to RTAs. The increasing number of vehicles and growth in urbanization consequent lead to increased RATEs, so it is essential to improve road traffic safety procedures. Countries such as Libya faced many precarious road safety problems by several factors including human factors, road factors, vehicle factors, and environmental factors. Without taking action, road traffic crashes are predicted to result in the deaths of around 1.9 million people annually by 2020. Approximately, only 28 countries, representing 416 million people (7% of the world’s population) have adequate laws that address all five risk factors (speed, drink-
driving, helmets, seat-belts, and child restraints) [2]. This study aims to investigate and classify the factors influencing the RTAs in Tripoli.

2. Literature review

The increasing number of private vehicles used in the city area has caused problems, such as traffic congestion, environmental pollution, and traffic accidents. Previous studies have shown some factors affecting accident in Tripoli, such as the increase in the number of private vehicles due to poor public transport in Tripoli [3]-[7]. Over 90% of victims of these accidents are in low-and-middle-income countries (approximately one million people). This difference continues when accounting for population distribution; the traffic casualty rate in countries of low-income was 17.4 per 100,000 people, and now they have highest annual road traffic fatality rates, at 24.1 per 100,000, while the rate in high-income countries was 12.6 and decreased to 9.2 per 100,000 [8]. Libya as a developing country is faced with the issue of excessive road crash rate. Figure 1 shows traffic fatality for several countries, and it is obvious that Libyan RTAs increased.

![Figure 1. Traffic fatality for selected countries [8].](image)

RTAs remain a worldwide public health issue. Presently placed ninth, RTAs are projected to become the fifth leading cause of death in 2030. Each year, over a million people perish worldwide as a consequence of RTAs, over 2500 casualties daily. Low and middle-income countries account for 90% of fatalities linked to RTA [8]. By 2030, road accidents are expected to become the fifth leading cause of accidents around the world [8]. Also, in high-income countries, traffic accidents are expected to reach 2% of the gross national product (GNP), while in middle-income and low-income countries it will reach 1.5% and 1% respectively [9]. In a study that has been in Tripoli-Libya, age and gender differences in traffic law knowledge and behavior of road users in Libya were investigated. The results indicated a distinction in (younger) males from females in the understanding of traffic laws. Males (18-25 years of age) are more likely to break traffic regulations than females in Tripoli-Libya. Road traffic crashes cannot be eliminated entirely. However, some casualties can be kept to the minimum or removed by simple protective measures like driver behavior, car conditions, road conditions, use of seatbelts and speed control [11].
3. Methodology
The quantitative technique was used in this study to collect data from the field of study, and the distribution of questionnaires was conducted to targeted drivers, pedestrians, passengers and also ordinary people. The questionnaire was designed with the objective of obtaining information from drivers, passengers, pedestrians to get more respondents about the factors affecting the RTAs in Libya. The questionnaire was grouped into four separate sections. The first part was regarding respondents’ personal information, while the second part was asking the respondents about their daily trip characteristics. Also, in the third section, the respondents were asked to answer the questions to assess the factors that are affecting the RTAs. In particular, this section was divided into four parts which include: human factors, vehicle factors, road factors, and environment factors. However, each part contains questions regarding each factor and its impact on the RTAs. Finally, subsequent remedial measures that may be taken to avoid more injuries and harm likely to occur by car accidents by giving their own opinion on closed-ended questions. Moreover, two ways were used to distribute the surveys; the first one is to create google forum on the internet to reach a large number of people, and this method was used to reach to the significant number of people in the short period compared to the second one which convenient way to distribute printed questionnaires. The questionnaire collected the data, and the number of respondents targeted was 400. The distribution of the questionnaire was in two ways, namely; online questionnaires by google form and printed questionnaires. Google form was constructive as it reached as many participants in a short time about 350 respondents which represent more than 85% of the total. The printed questionnaire needs more time to distribute to the respondents, about 50 which represents less than 15% of the total respondents as shown in Figure 2.

![Figure 2. Distribution of questionnaire on the respondents.](image)

4. Results and discussions
4.1 Demographic characteristics
For instance part of the demographic information, the research requested the respondents to indicate their gender, age, marital status, occupation, nationality, education level, income per month and also the place of work or study. This information required to have more information about the respondents who represent a random sample of the study. The respondents of the questionnaire were 400, where the target
group was road users involved in RTAs such as; drivers, passengers, and pedestrians, 78.5% of respondents were males while 21.5% were females as listed in Figure 3.

Figure 3. Gender frequency and percentage.

The age of respondents as shown in Table 1 it was divided into four sections, which starts from 18 years until more than 45 years. It was noted that the majority of the respondents were between 26 and 35 years old with 41.5%. The second highest percentage was between the ages of 18 - 25 years with 32.8%, while 7% of their age was more than 45 years old. The results indicate that there was a significantly good proportion of young respondents, which might mean the probability to obtain significant results as the young drivers are more involved in the RTAs.

| Ages (Years) | Frequency | Percent | Cumulative % |
|--------------|-----------|---------|--------------|
| 18 - 25      | 131       | 32.8    | 32.8         |
| 26 - 35      | 166       | 41.5    | 74.3         |
| 36 – 45      | 75        | 18.8    | 93.0         |
| > 45         | 28        | 7.0     | 100          |
| Total        | 400       | 100     |              |

4.2 Education level
The education level is critical in this study as educated people have awareness about any phenomenon and issues more than poorly educated. Figure 3 shows the education profile of the respondents was 88.3% of respondents were educated to undergraduate or post-graduate level and 9.3% were educated to the high school level. Moreover, 2% were educated to less than high school, and a slight number of respondents were with no qualification 0.5%. Therefore, most of the applicants have been educated to a high level, so they must entirely understand and critically review the issues of traffic and get benefits from its awareness programs;
4.3 Driving experience

The experience in driving including obtaining a license can be seen that a majority of respondents were had to experience more than 12 years with a rate of 29.8%. Also, 22.8% of respondents were had experience in driving between 8 and 12 years, while 47.5 % of respondents were less than 8 years’ experience driving as demonstrated in Table 2.

| Years  | Frequency | Percent | Valid | Cumulative% |
|--------|-----------|---------|-------|-------------|
| 1-3    | 79        | 19.8    | 19.8  | 19.8        |
| 4-7    | 111       | 27.8    | 27.8  | 47.5        |
| 8-12   | 91        | 22.8    | 22.8  | 70.3        |
| > 12   | 119       | 29.8    | 29.8  | 100         |
| Total  | 400       | 100     | 100   |             |

4.4 Human factors group

Human factors are one of the most critical factors affecting RTAs in Tripoli. The results show that many accidents occur as a result of these factors. Therefore these factors should be considered in particular to reduce these accidents, which leads to minimizing the casualties resulting from those accidents. Table 3 shows the human factors which the first group of elements in the questionnaire; this group contains nine factors, where the impact and importance of these factors vary from one factor to another. Hence, these factors were classified according to the significance of each of these factors and their impact on road accidents in Tripoli.
Table 3. Ranking of human factors group.

| Factors No. | Factor description                     | RII  | Group | Overall |
|-------------|----------------------------------------|------|-------|---------|
| 1           | Decision-making ability                | 0.755| 4     | 9       |
| 2           | Disobedience to driving codes          | 0.844| 2     | 2       |
| 3           | Drinking /taking drugs and driving     | 0.737| 6     | 13      |
| 4           | Following the vehicle in front too closely | 0.752| 5     | 10      |
| 5           | Inexperienced drivers                 | 0.723| 8     | 17      |
| 6           | Over-speeding                         | 0.855| 1     | 1       |
| 7           | Passenger’s attitude                  | 0.706| 9     | 22      |
| 8           | Sleepiness and fatigue                | 0.729| 7     | 15      |
| 9           | Using a mobile phone                  | 0.812| 3     | 4       |

It was observed from Table 3 that over-speeding was the most effective factor among the human factors. Also, it has the most effect in the overall groups, which means this factor has a significant impact on the RTAs in Tripoli with a value of RII 0.855. The second factor which has a considerable effect on RTAs was the disobedience to driving code such as children who are playing with the car on the roads which also ranked as the second overall group with the RII value of 0.844. In Libya, it is a typical behavior that children are playing with cars on intercity road networks due to the less awareness of kids. Therefore, it is essential to pay attention to these issues. Also, ignoring the road control devised such as signs and traffic lights which only way to control driver’s behavior on road networks results in many accidents and that causes an increase in injuries and fatalities. Using a mobile phone during driving or crossing streets was as accepted has a significant influence on RTAs, it was ranked the third factor affecting the human factors group, while it ranks as fourth in overall categories with a value of RII was 0.812. Using mobile phones considered one of the most critical factors that lead to the occurrence of severe accidents worldwide due to a lack of attention to the geometry of roads and objects on the streets during driving. The Sleepiness and fatigue, inexperienced drivers and passenger attitude were classified as the last factors in this group, where the ranked in seventh, eighth and ninth with RII of 0.729, 0.723 and 0.706 respectively. The distances inner the city is not that far to make the drivers be under stress that is why this factor has a low impact on the other factors. Also, inexperienced drivers are not that significant matter since all of the Libyan start driving at a young age like 12-13 years old without any driving license, so most of the drives have the initial experience. Regarding passenger’s attitude, in recent years the altitude of Libyan drivers enhanced because of the blockage of low and the proliferation of weapons inside the city.

4.5 Vehicle factors

The vehicle factors contain several factors that might increase the possibility of accidents occurring on the roads in the city of Tripoli, where the importance of these factors varies among each other regarding their impact on RTAs and Table 4 demonstrations the ranking of those factors regarding their importance. From Table 4, it was found that poor brake or brake failure has great implications on RTAs as ranked the first factor in the group and the fifth factor in the overall categories with RII of 0.808. Furthermore, the faulty light factor is classified as the second factor affecting the RTAs in the group, and fourteenth in overall the groups with RII of 0.73 which means it has a medium effect on the RTAs in Tripoli. Also, the bad tires were ranked as the third factor affecting RTAs in this group, while it was classified as sixteenth in the overall of the groups with RII of 0.726. From field observation it’s well known that the Libyans usually do not care about changing tires unless it explodes, this indicates that
they are careless and put their lives at risk due to the possibility of increased risk of accidents due to the tire explosion.

Table 4. Ranking of vehicle factors.

| Factors No. | Factor Description                | RII   | Group | Overall |
|-------------|-----------------------------------|-------|-------|---------|
| 1           | The absence of rear view          | 0.705 | 4     | 23      |
| 2           | Bad tires                         | 0.726 | 3     | 16      |
| 3           | Breakdown of engine               | 0.576 | 7     | 30      |
| 4           | Defective horns                   | 0.52  | 10    | 33      |
| 5           | Defective steering                | 0.562 | 8     | 31      |
| 6           | Faulty gearbox                    | 0.5415| 9     | 32      |
| 7           | Faulty light                      | 0.73  | 2     | 14      |
| 8           | Poor brakes/brake failure         | 0.808 | 1     | 5       |
| 9           | Windshield (break, not clean)     | 0.614 | 5     | 27      |
| 10          | Other mechanical failures         | 0.587 | 6     | 29      |

4.6 Road factors group

The road humps factor ranked as the 4th causing factor in the group while it is listed as the 8th in overall groups with RII of 0.7625. The absence of illuminated roads due to the shortage of electric nowadays with over-speed and illegal humps which constructed by residents without following humps standards then the increase in accidents will be an inevitable consequence of all those factors. Further, the roadway geometrics and Animals out of control (e.g., cows, dogs) factors have the same rank 5th in the road factors group resulted in the same listed in all groups 18th with 0.717 RII. The roadway geometrics is not the main problem, but the lacked sings in the road networks is the primary matter, as the drives will not recognize for example the T-junction of deep left or right curves and allowable speed on the curve which all depends on the experience of the drivers. On the other hand the low in Libya stand with the owners of animals in any collusion, the driver must pay the offense in case of a collision with an animal which leads to careless of the owners regarding controlling their animals. The road site details (e.g., steep hill, narrow road, bend/winding road, slippery road) factor has a slight effect on the RTAs, which is located at the 7th effecting factor in the group and it is ranked as the 20th in overall with RII 0.7155 as shown in Table 5. Meanwhile, the factors such as regularly roadworks and the road surroundings (e.g., buildings, fences, and vegetation) were found to have the values of RII 0.634 and 0.6115 respectively, the value of RII less than 0.7 which means they have no adequate effects on the RTAs in Tripoli. In General, illumination is essential to ensure the safety of road users, and emphasis on street lighting is necessary to reduce accidents. On the other hand, the existence of roads signings one of the sufficient keys to guide the drivers and in the lack of knowledge of the roads networks, while the poor road surface factor also is so crucial in term of efficient on the RTAs, as there are many holes and cracks in the roads, that may lead to the punctured tires and damaged of vehicles as well as increase fuel consumption, therefore it is essential to perform a regular maintenance to road networks to prevent accident-related to poor road service.

Table 5. Ranking of road factors.

| Factors No. | Factor Description         | RII   | Group | Overall |
|-------------|----------------------------|-------|-------|---------|
| 1           | Poor road surface          | 0.785 | 3     | 7       |
| 2           | Poor/no street lighting    | 0.827 | 1     | 3       |
| 3           | Insufficient signing       | 0.783 | 2     | 6       |
| 4           | Road humps                 | 0.763 | 4     | 8       |
| 5           | Regularly roadworks        | 0.634 | 8     | 26      |
| 6           | Road surroundings          | 0.612 | 9     | 28      |
| 7           | Animals out of control     | 0.717 | 5     | 18      |
| 8           | Road site details          | 0.716 | 7     | 20      |
| 9           | Roadway geometrics         | 0.717 | 5     | 18      |
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4.7 Environmental factors group

The environmental factors group considered one of the groups that may affect RTAs. This category contains a small number of factors when compared with other groups. However, it provides essential factors that have a significant impact on RTAs in Tripoli. The results displayed in Table 6 show that the glare which the difficulty in seeing in the presence of bright light factor is the first factor affecting the environmental factors group and it is ranked as tenth in overall groups with RII 0.752, which indicates a moderate effect on the RTAs.

| Factors NO. | Factor Description                       | RII  | Group | Overall |
|------------|-----------------------------------------|------|-------|---------|
| 1          | Slick roads                             | 0.664| 4     | 24      |
| 2          | Glare                                   | 0.752| 1     | 10      |
| 3          | View obstructions                       | 0.748| 2     | 12      |
| 4          | Other highway-related conditions        | 0.641| 5     | 25      |
| 5          | Weather conditions                      | 0.715| 3     | 20      |

5. Conclusions

The results show that the factors differ in their impact on RTAs from one factor to another. Each factor has a specific effect on RTAs, some of them have high effects and lead to increase RTAs, and others have moderate effects while there are some factors with slight impact or without impact on RTAs. Also, the major contributing cause of many crashes as observed in the results is driver error. The human errors leading to highway crashes are related to the complex interaction for the driver’s psychological and physiological condition, the system design, and the existing environmental condition. The driver’s actions that lead to errors include driving at an inappropriate speed or over speeding which ranked as first among all factors 84% for existing physical and/or environmental conditions, driver inattentiveness, failure to yield the right-of-way, wrongly negotiating curves, the use of mobile phones. Moreover, driver’s disobedience to driving code with 81% has significant impacts on the RTAs. The main aim of the traffic engineer regarding human factors in Tripoli networks to ensure safety is to understand how
those factors influence the drivers so that the probability of occurrence of these associated safety consequences of these factors is reduced. For example, in the city of Tripoli rumple strips are placed at side and medians of high-speed roads in rural areas to alert inattentive or sleepy drivers when they are leaving the travel lane. The mechanical situation of an automobile might be involved in highway crashes which known as vehicle factors group. Faulty breaks in vehicles were the 1st-factor affecting RTAs with more than 74% compared to other factors; this indicates a higher influence on the RTAs. The 2nd influencing was Faulty light approximately 61% of respondents seeing this factor significantly affecting the RTAs followed by other factors such as worn tiers. However, many vehicle manufacturers are now installing in-vehicle equipment that helps to reduce the potential of the vehicle being involved in crashes and/or the severity of a collision when the vehicle is involved in one. These include seat belt reminders, antilock braking systems (ABS), collision avoidance sensor and speed limiter/intelligent speed adaption. In Libyan, due to the political issues and lacking in control of the importing of vehicles the condition was not in good condition, which was prohibited before the current situation. In this case, the government should take action to reduce these issues and importing the vehicles which installing all safety equipment. Furthermore, the quality and the condition of the roads is one of the factors involve the RTAs. As a result, the highway needs to be designed to afford adequate stopping sight distance (SSD) at the design speed. Otherwise, the drivers will be incompetent to take remedial actions to evade the accidents. One of the solutions, traffic signs should afford sufficient SSD when the sings go from green to yellow and then to red. In Libya, the pavement surface is in a critical situation and most of the roads need to be reconstructed at the time of maintenance is over. Moreover, the signs should be placed on the importance of the information contained in them and avoid placing it at the location where they are not necessary or essential. Also, in situations where the required information cannot be placed on one sign or several signs at a single location, the information should be given in portions along the road to reduce the information load. The physical and climatic environment surrounding an automobile are factors occurrence of highway accidents; the most common environmental factor is the weather. Weather conditions are the primary road accidents contribution to the highway, but as shown from the results in the city of Tripoli, it has a slight impact on RTAs. The fog has been caused many severe accidents because vehicles traveling at high speeds are not capable of realizing other automobiles have been ahead that may have slowed down or stopped. Recommendations to Stakeholders’ that should be taken into consideration for the government, to reduce RTAs in Tripoli, to achieve the objective of this research.

- Over Speed is the most critical factor affecting RTAs in Tripoli, where the majority of respondents considered that speeding has a massive impact on the increase in accidents. Recently, it has also been noted that the rate of accidents has been increased as a result of extreme speed and this has resulted in increased casualties. Hence, the government should increase awareness of the dangers of speed by giving specialists to lectures in high schools and universities to increase awareness of accidents as a result of excessive speed. Moreover, the government should also install speed-monitoring cameras in all places, as well as increase traffic campaigns and punish those who exceed the speed limit with high fines that may reach to high penalties and withdrawal of license.
- The handling of mobile phones during driving is one of the reasons for the increase in RTAs. Hence, awareness campaigns should be conducted regarding the dangers of using phones while driving, also not being lenient in performing traffic violations. Additionally, the use of a mobile phone for pedestrians while crossing the roads leads to increased accidents; pedestrians must be alerted and warned not to use the phones while crossing the roads.
- Obtaining a driver's license in Libya has become very easy so that it reached the stage where the driver's license can be obtained without a driving test. Either paying a bribe to a traffic man or knowing someone in the traffic department, which leads to many crimes regarding increasing accident rates thus increasing the proportion of casualties. Hence, the emphasis should be on the issue of obtaining driving licenses. So the traffic man participatory in giving the license without an exam should be expelled.
- Most of the participants considered that the roads in Libya are terrible and need many improvements. The government should pay attention to these roads regarding providing
functional lighting. The government should also ensure a good quality of the road surfaces and make the periodic maintenance of these roads. Also, providing road signs and especially roads linking cities.

- The public transport system in Libya is inadequate and almost is non-existent, which leads to an increase in the percentage of vehicles, resulting in increased traffic congestion and increased accidents. The government should concern to public transport, establish trains and an excellent public transport system to reduce RTAs.

References
[1] S. Ameratunga, M. Hijar, and R. Norton, Road-traffic injuries: confronting disparities to address a global-health problem. Lancet, 2006. 367(9521): p. 1533-1540.
[2] World Health Organization. (2013). Global status report on road safety 2013: supporting a decade of action: summary.
[3] A. Ishtiaque. "Road infrastructure and road safety." Transport and Communications Bulletin for Asia and the Pacific 83 (2013): 19-25.
[4] S. I. Albrka, A. Ismail, H. A. Yahia, M. A. Ladin. Application of Transyt-7F on signalised road junction networks in Shah Alam and Petaling Jaya. Jurnal Teknologi. 2014 Feb 15;69 (2).
[5] A. A. Hammoudi, "Causes and strategies to reduce road traffic accidents in Abu Dhabi." PhD diss., Cardiff Metropolitan University, 2014.
[6] A. Ismail and H. A. Yahia, H. A. M. (2011). Causes and effects of road traffic accidents in Tripoli–Libya. ISBN 978-602-8605-08-3.
[7] K. B. Lankarani, S. T. Heydari, M. R. Aghabeigi, G. Moafian, A. Hoseinzadeh, and M. Vossoughi. (2014). The impact of environmental factors on traffic accidents in Iran. Journal of injury and violence research, 6(2), 64.
[8] World Health Organization. (2009). European status report on road safety. WHO Regional Office for Europe.
[9] S. M. Sabbour, and J. M Ibrahim. (2010). Driving behavior, driver style and road traffic accidents among the young medical group. Injury Prevention, 16(1), A33.
[10] World Health Organization. (2015). Global status report on road safety 2015. World Health Organization.
[11] H. A. M. Yahia, A. Ismail, S. I. Albrka, A. S. Almselati, and M.A. Ladin. (2014). Attitudes and awareness of traffic safety among drivers in Tripoli-Libya. Research Journal of Applied Sciences, Engineering and Technology, 7(24), 5297–5303.