Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

**Original Research Article**

# Assessment of Road Traffic Accidents on Southwest Nigeria Intercity Highways

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**ARTICLE INFORMATION**

*Article history*:
Received 15 April, 2019
Revised 20 May, 2019
Accepted 24 May, 2019
Available online 30 June, 2019

*Keywords*:
Bayesian
Fault tree
Road traffic accident
Road obstruction
Highways

**ABSTRACT**

*Road traffic accidents have posed a threat to the safety of human life. As estimated, 1.2 million people die each year in road traffic accident and more than 50 million are injured worldwide. This study was aimed at identifying road traffic accident hazards and developing a model that predicts the occurrence of road traffic accident. Data were collected from a State Command of Nigeria's Federal Road Safety Corps (FRSC) and analyzed using fault tree analysis (FTA) and Bayesian belief network (BBN). The fault tree identified and modeled 18 hazards. The fault tree developed is a system of OR gates for all connection of events. The model predicts the probability of road traffic accident to be 0.73. Important measure analysis was also established based on the weight of the hazards. The hazards with the greatest contribution to road traffic accident were sleeping on steering and overloading and the hazard with the least contribution was loss of concentration. BBN identified and modeled seven hazards. Bayesian influence diagram, conditional probability table and Bayesian probability expression were developed for the occurrence of road traffic accident. The model predicted that the probability of road traffic accident is 0.59. Bayesian diagnostic inference shows that lack of concentration has the greatest contribution to road traffic accident occurrence while loss of control has the least contribution. The model developed can be useful for advising government's road safety agency on the likelihood of road traffic accident occurrence and the indicators to road safety preventive strategies.*



## 1. INTRODUCTION

Transportation is a process that involves movement of man, goods and services from a given point of origin to specific destination. Transportation affects every human being in the course of their daily activities and it is difficult to conceive a situation where transportation does not play significant role in the life of any

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individual (Gbadamosi, 2002). Transportation helps to achieve the basic objectives of living in the city which is the functional efficiency of land uses, infrastructure, services and improvement in the quality of life (Odugbemi, 2010). The structure, size vertical and horizontal spreads of any city are dependent on the nature and function of transport system. As a result of these, the ease, the spread, the cost and quality of movement between land uses and places in the cities are inextricably guaranteed with the transport system and directly linked with planning system (Osoba, 2012).

Although transportation has liberated man and makes him more mobile, his increasing reliance on vehicular movement has bestowed great facilities on him and his activities. This is why in the literature; it is described as the maker and breaker of the cities. Ogunsanya (2002) confirmed how transportation has built cities over the years in some urban areas in Nigeria and its menace especially on prevalence of its accident.

A highway is any route with public right access which links a city to another. Its economic benefit could be multiple, some of which includes job creation (a wide range of jobs from the planning phase to the actual completion of the road, even after the completion for those that will maintain the road), quick delivery of good and services (intercity highways made delivery of products ease and quick), better life (one can live in one's comfort zone and work in the city due to good highway) (Odugbemi, 2010). A good highway often aids fast and easy travels and tourism. This will not only increase revenue for the authority but improve standard of living in such areas (Odugbemi, 2010).

The transportation system could be through several modes but most popular means is road transportation of which road traffic accident (RTA) is the most disturbing consequence of its use. RTA is a global issue and its trauma remains a significant concern and a leading cause of mortality and morbidity, with road traffic injuries predicted to be the 5th leading cause of mortality, globally by 2030 (WHO, 2013). In the developing nations like Nigeria, the number of motor vehicles is generally much lower than in the developed ones, yet fatalities from road crashes are higher (Gbadamosi, 2002). It costs almost one percent of these developing nations annual gross national product utilizing scarce financial resources they can ill-afford to lose (Gbadamosi, 2002). Nigeria, with a total land area of 910,771 square kilometers and human population of about 167 million, is the most populous country in Africa, and the 7th most populous nation in the world. Its large land mass and burgeoning population correlate with its high level of vehicular population estimated at over 7.6 million with a total road length of about 194,000 kilometers (comprising 34, 120 km of Federal, 30,500 km of States and 129,580 km of local roads) (FRSC, 2012). Nigeria population density varies in rural and urban areas (approximately 51.7% and 48.3% respectively) which translate to a population- road ratio of 860 persons per square kilometers indicating intense traffic pressure on the available road network. This pressure contributes to the high RTA in the country (FRSC, 2012). The Nigeria situation has reached such an alarming proportion even to the point of sheer frustration and near helplessness. Nigeria continues to feature in the bottom half of World Health Organization (WHO) country rankings of RTA. The country's 149th ranking in 2009 out of 178 member states indicates the hazards associated with road transportation in a country that is mostly dependent on its road network for economic, social and physical activities (Sumaila, 2013).

Thus, the government and Nigerians are deeply worried about the persistent of its high rate and preventable consequential waste of lives and properties. It is worrisome that road traffic crashes and mortality rates are still high in Nigeria despite various remedial measures taken in recent years to combat the menace. This development obviously suggests the need to further safety program interventions at deciphering the glitches. Nigeria being ranked second amongst countries with largest road network, the prediction of likelihood occurrence of RTA is scarcely reported. Although highway safety is greatly on ground but the fatality rate of RTA is on the rise. Safety is an essential component of transportation engineering. The safety of road transportation involves numerous factors including driver skills, roadway characteristics, vehicle conditions, and weather. In addition to causes of crash, the identification of hazards that may increase severity in the event of a crash is important. Prominent among published works in this area include those of Abbas (2012),

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Ahmad et al. (2012), Aworemi et al. (2010), Memon (2012), Jadaan et al. (2014), Mohammad et al. (2016), Kareem et al. (2012), Sumaila, (2013) and Usman et al. (2015). These works have extensively discussed statistical modelling of RTA, road safety, causal factors contribution to RTA and its probability assessment fatality. Data have also shown that efforts are being effective in preventing it, but incidences and their corresponding severity still indicates a very high risk. Network Science methods have been used to predict the likelihood of accident in the aviation and manufacturing industry but these methods have not been explored in the road transportation sector. Akinyemi and Adebiyi (2015) and Akinyemi and Adebiyi (2016) have used fault tree analysis (FTA) and Bayesian Belief Network (BBN) to model the probability of accident occurrence in aviation and manufacturing industry respectively. This research work therefore aimed at assessing the risk of road traffic accident occurrence on intercity highways in Nigeria using FTA and BBN methods.

## 2. MATERIALS AND METHODS

### 2.1. Road Traffic Accident Hazards Identification

Hazards are potentially harmful source or situation which can cause injury, death or destruction of property. In other words, hazards lead to accident and can occur usually due to several causes. Some of the hazards that exist in relation to roads include:

a. Pot holes
b. Sharp bends
c. Uneven/undulating road surface
d. Brake failure
e. Excess exhaust fumes or smokes leading temporary road blindness for vehicle behind
f. Failed wiper during raining season
g. Loose wheel nut
h. Indiscriminate parking
i. Faulty wheel balancing and alignment

Road traffic accident records of Federal Road Safety Cooperation (FRSC), Ogun State chapter (Ogun State was adjudged to had witnessed highest RTA mortality rate in South Western Nigeria in 2016 alone) and was investigated for possible identification of road accident hazards.

### 2.2. Construction of Fault Tree

The undesired event is road traffic accident. In constructing the fault tree, question such as “how can this happen?” or “what will cause this to occur?” were asked. Although the questioning process could continue indefinitely, problems arising from outside the boundary were not addressed.

#### 2.2.1. Qualitative and quantitative analysis of fault tree

The shape/structure of the fault tree was analyzed qualitatively in order to understand the causation mechanism of road accident occurrence. Common causes of road accident hazards were identified and this contributed to the reduction redundancy in the fault tree. Quantitatively, the mathematical expression for probability of occurrence of road traffic accident (RTA) is given in Equation 1:

$$\mathrm{Prob(RTA)} = 1 - \prod_{i=1}^{n}(1 - \mathrm{BEi}) \tag{1}$$

Where: Prob (RTA) = the probability of road traffic accident, BEi = probability of occurrence of basic events (road traffic accident hazards) and n = the number of basic events (road traffic accident hazards)

### 2.3. Bayesian Probability

Bayesian probabilistic expression was developed in order to know the state of the road traffic accident hazards. Bayesian network is the manipulation of conditional probability. According to Gavin *et al.* (2015), Bayesian network has considerable potential for use as tools to assess the validity of research evidence. The key strength of such networks lies in the provision of a statistically coherent method for combining probabilities across a complex framework based on both belief and evidence.

#### 2.3.1. Construction of Bayesian network (BN) model

In this study eighteen road traffic accident hazards were identified which were grouped into intermediate and basic according to the fault tree. Bayesian network was used to determine the probability of consequence magnitude of road accident given the occurrence of road hazards. An influence diagram showing the relationship between road traffic accident hazards (parent node) and the consequence magnitude of road traffic accident (child node) was developed. Conditional probability table (CPT) was generated for both intermediate road traffic accident hazards (parent node) and road traffic accident (child node). It should be noted that in a CPT, the probability expression is replaced by probability values between 0 and 1. In this case these values were obtained from expert opinion.

#### 2.3.2. Estimation of prior probability and conditional probability of node variables

After establishment of BN influence diagram for the occurrence of consequence/magnitude of road traffic accident, historical data were used to estimate the prior probability of the parent node. The data used in this study was obtained from FRSC.

#### 2.3.3. Bayesian network inference

The probability of road traffic accident occurrence needed to be improved to address the occurrence of consequence magnitude. The scenario that generates the consequence magnitude is the occurrence of road traffic accident hazards. The probability of road traffic accident magnitude can be decomposed into two broad components namely:

i. The probability of occurrence of state of road traffic accident hazards.

ii. The probability of occurrence of road traffic accident given the occurrence of each combination of state of road traffic accident hazard.

Mathematical expression for probability of occurrence of Road Traffic Accident (RTA) is Yes or No is given by:

$$P(Wi) = \sum_{j=1}^{m} \left( P(Hj) \times \prod_{k=1} m\, P(Wi|pa(Wi,k) \right) \tag{2}$$

Where: P (Wi) = probability of occurrence (RTA= Yes and No) of consequence magnitude of road traffic accident hazard, P (Hj) = joint probability occurrence of road traffic accident hazards state, $\prod_{k=1} m\, P(Wi|pa(Wi,k)$ = conditional probability of occurrence of consequence magnitude given the occurrence of k combination states of parents' node of variable Wi, n = the number road traffic accident hazards and m = number of states (combination of states = 128) of parent nodes.

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## 3. RESULTS AND DISCUSSION

### 3.1. Road Traffic Accident Hazards

Table 1 present the road traffic accident hazards identified from accident records of FRSC, Ogun State Command. The road traffic accident hazards abbreviations are presented in Table 2. The data collected from FRCS, Ogun State Command was used to estimate the probability of the basic events using frequentist method and this was presented in Table 3.

Table 1: Road traffic accident hazards

| S/n | Hazard | Type of event |
|---|---|---|
| 1. | Speed violation | Basic |
| 2. | Loss of control | Basic |
| 3. | Careless driving | Intermediate |
| 4. | Wrong overtaking | Basic |
| 5. | Dangerous overtaking | Basic |
| 6. | Dangerous driving | Basic |
| 7. | Bad road | Basic |
| 8. | Overloading | Basic |
| 9. | Tyre burst | Basic |
| 10. | Brake failure | Basic |
| 11. | Mechanical deficient vehicle | Basic |
| 12. | Route violation | Basic |
| 13. | Lack of concentration | Intermediate |
| 14. | Use of phone while driving | Basic |
| 15. | Sleeping on steering | Basic |
| 16. | Road obstruction | Basic |
| 17. | Suspension System Failure | Intermediate |
| 18. | Mechanical factor | intermediate |

Table 2: Road traffic accident hazards abbreviations

| S/n | ID | Description of event |
|---|---|---|
| 1 | SPV | Speed violation |
| 2 | LOC | Loss of control |
| 3 | TBT | Tyre burst |
| 4 | WOV | Wrongful overtaking |
| 5 | BRD | Bad road |
| 6 | RTV | Route violation |
| 7 | OVL | Overloading |
| 8 | DOT | Dangerous overtaking |
| 9 | DGD | Dangerous driving |
| 10 | ROS/OBS | Road obstruction |
| 11 | SOS | Sleeping on steering |
| 12 | UPWD | Use of phone while driving |
| 13 | BFL | Break failure |
| 14 | MDV | Mechanical deficient vehicle |
| 15 | MF | Mechanical Factor |
| 16 | CD | Careless driving |
| 17 | LCN | Lack of concentration |
| 18 | SSF | Suspension system failure |

Table 3: Weight of the road traffic accident hazards (basic events) and their description

| S/n | ID | Description of event | Probability |
|---|---|---|---|
| 1 | BE1 | Use of phone while driving | 0 |
| 2 | BE2 | Sleeping on steering | 0.006 |
| 3 | BE3 | Bad road | 0.009 |
| 4 | BE4 | Overloading | 0.006 |
| 5 | BE5 | Tyre burst | 0.07 |
| 6 | BE6 | Break failure | 0.099 |
| 7 | BE7 | Mechanical deficient vehicle | 0.014 |
| 8 | BE8 | Wrong overtaking | 0.11 |
| 9 | BE9 | Dangerous driving | 0.05 |
| 10 | BE10 | Dangerous overtaking | 0 |
| 11 | BE11 | Speed violation | 0.45 |
| 12 | BE12 | Loss of control | 0.13 |
| 13 | BE13 | Route violation | 0.04 |
| 14 | BE14 | Road obstruction | 0.014 |

### 3.2. Fault Tree Analysis (FTA)

Fault tree analysis (FTA) can be define as a top down approach that started from the unwanted consequences as top event and identify all factors that could contribute to the top event. This section discussed fault tree analysis of road traffic accidents occurrence in Ogun state, in which six hundred and thirty-two (632) accidents were recorded within the period of January 2016 – April 2017. Eighteen (18) road traffic accidents hazards were identified and modeled on a fault tree. The fault tree developed is a system of OR- gates for all connection of events as shown in Figure 1 below. The top event (road traffic accident) occurs if at least one of the road accident causal factors occurs. From Equation 1, the probability of road traffic accident is:

$$Prob(RTA) = 1 - \prod_{i=1}^{44}(1 - BEi)$$

$$P(RTA) = 1 - (1 - 0.045) \times (1 - 0.13) \times (1 - 0.07) \times (1 - 0.11) \times (1 - 0.01) \times (1 - 0.04) \times (1 - 0.01) \times (1 - 0)) \times (1 - 0.05) \times (1 - 0.014) \times (1 - 0.01) \times (1 - 0) \times (1 - 0.99) \times (1 - 0.014) = 0.73$$

The quantitative analysis has successfully captured the entire causal factor in the event of road traffic accident with probability of 73% chance of occurrence.

Furthermore, Kim and Yang (2012) as well as Akinyemi and Adebiyi (2015) described the fault tree importance measure and how they help in decision making. Fussell-Vesley (FV) and risk reduction worth (RRW) were used for importance measure. The importance measure result for each basic event is shown in Table 4.

The event with greatest contribution to road accident is sleeping on steering and overloading followed by bad road, mechanical deficient vehicle others are road obstruction, route violation, dangerous driving, tyre burst, break failure, wrong overtaking, loss of concentration and speed violation which have least contribution with FV value of 1.62. The FV value, which represents the contribution of hazards to systematic risk, show that sleeping on steering and overloading, bad road, mechanical deficient vehicle and road obstruction, contributed more to the system risk. However, use of phone while driving and dangerous overtaking has no effect on road accident within the period of January 2016 – April 2017. This is evident because there was no accident caused by these two road accident hazards. In actual fact, these hazards are major causes of road accident.

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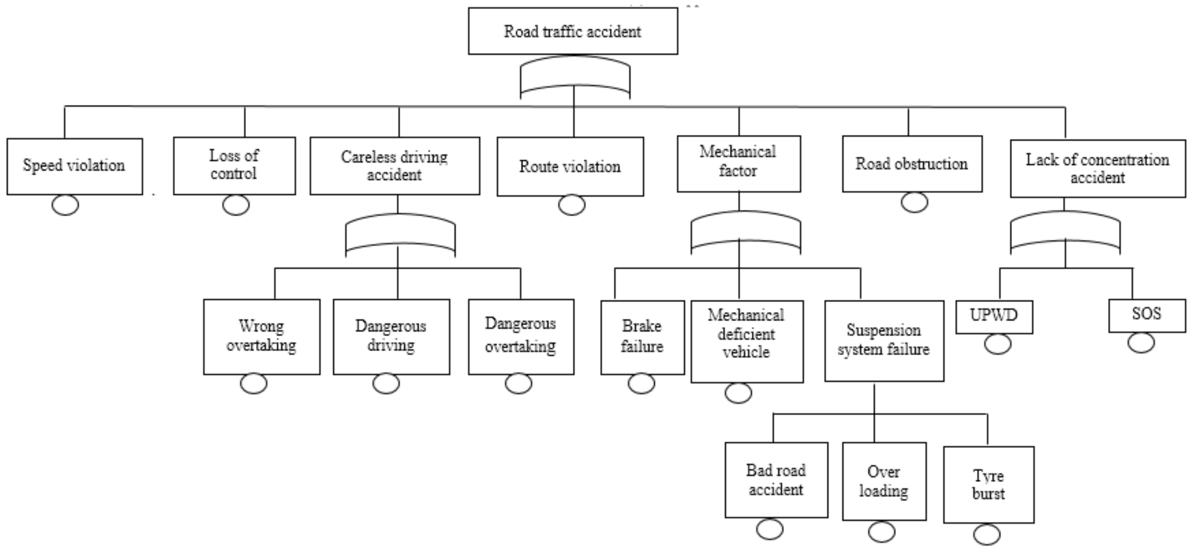


Figure 1: Fault tree diagram for road accident hazard after qualitative evaluation

Table 4: Results of importance measure analysis of road traffic accident hazards

| S/N | ID | Probability of occurrence of road accident causal factor | FV $F^0/F^1$ | $RRW = 1 - 1/FV$ |
|---|---|---|---|---|
| 1. | BE2 | 0.006 | 121.7 | 0.9917 |
| 2. | BE4 | 0.006 | 121.7 | 0.9917 |
| 3. | BE3 | 0.009 | 81.1 | 0.9877 |
| 4. | BE7 | 0.014 | 52.1 | 0.9809 |
| 5. | BE14 | 0.014 | 52.1 | 0.9809 |
| 6. | BE13 | 0.04 | 18.3 | 0.9452 |
| 7. | BE9 | 0.05 | 14.6 | 0.9315 |
| 8. | BE5 | 0.07 | 10.4 | 0.9041 |
| 9. | BE6 | 0.099 | 7.4 | 0.8644 |
| 10. | BE8 | 0.11 | 6.7 | 0.8493 |
| 11. | BE12 | 0.13 | 5.6 | 0.8219 |
| 12. | BE11 | 0.45 | 1.6 | 0.3835 |
| 13. | BE1 | 0 | 0 | 0 |
| 14. | BE10 | 0 | 0 | 0 |

$F^0$ is probability of road accident, $F^i$ = probability of occurrence of road accident causal factor

RRW, whose objective is to determine the best solution for solving system's hazards has the same result as FV. The most important hazards are sleeping on steering, overloading, bad road, mechanical deficient vehicle and road obstruction. Dangerous driving, tyre burst, break Failure, Wrong overtaking Loss of Control, and Loss of control contribute less to the system risk. The road traffic accident causal factors that contribute more to system risk should be given priority in order to reduce road traffic accident.

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### 3.3. Bayesian Network Analysis

Most of the techniques used for modeling crashes require a prior knowledge of the distribution of crash parameters. Sometimes the knowledge about a distribution is not directly known but instead the statistical dependencies or independencies among the variables are known e.g. vehicle speed and severity of the crash. The dependency between accident occurrence and mechanical factors such as suspension system failure and human factor such as sleeping on steering etc. could also be established. The internal dependencies could then be represented by conditional probabilities which could be used to determine the likelihood of the magnitude of crashes in a particular roadway segment given certain conditions. Bayesian belief networks are appropriate for modeling crashes occurrence due to the fact that the dependencies between factors are known and are used to construct the belief network structure. Bayesian networks combine graphical structure (with child node which is road traffic accident and parent node which is the hazard). For this study road traffic accident hazards were categorized into Seven (7) which acted as the parent nodes in the influence diagram of BBN influencing the child node which is road traffic accident as shown in Figure 2. The prior probability for the seven (7) hazards was given in the Table 5.

It should be noted that prior probability was estimated using the frequency of occurrence of road traffic accident; for instance, speed violation (SPV) occur 287 times given an estimated probability of 0.45 (45%). Table 5 shows the state and the prior probability of the parent nodes.

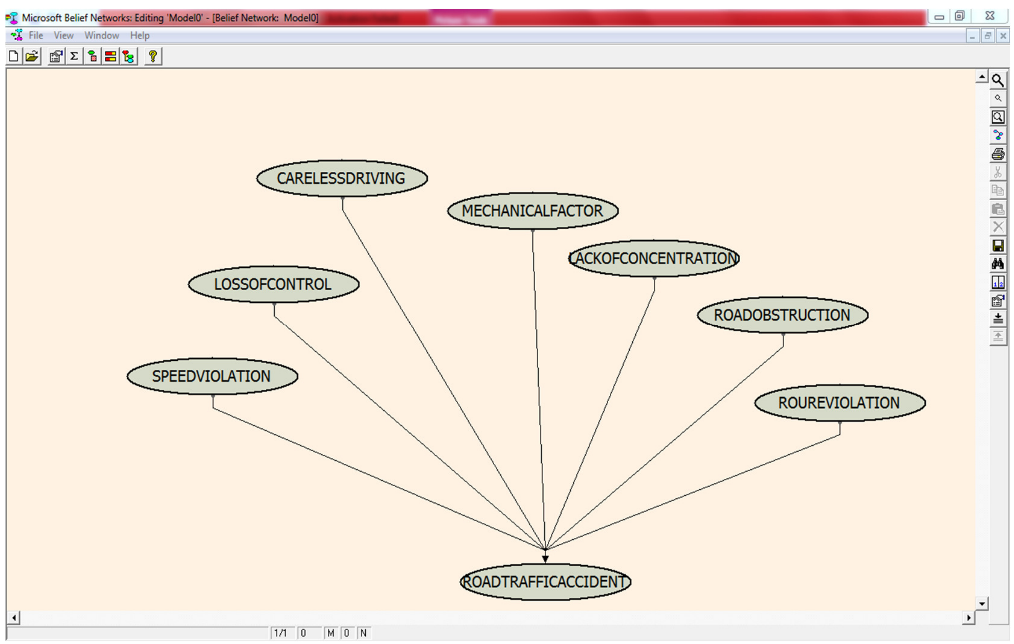


Figure 2: Influence diagram for relationship road hazard and consequence magnitude

The parent nodes (road traffic accident hazards) has two states respectively namely; speed violation (Yes and No), careless driving (Yes and No), Road obstruction (Yes and No), Loss of control (Yes and No), Mechanical factor (Good and Bad), Route violation (Yes and No), Lack of concentration (Yes and No). Table 6 shows the conditional probability of road traffic accident (child node) given the occurrence of states of parent nodes.

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Table 5: Prior probability of road traffic accident hazards

| S/N | Variables | State | Prior probability |
|---|---|---|---|
| 1 | SPV | Yes | 0.55 |
| | | No | 0.45 |
| 2 | CD | Yes | 0.55 |
| | | No | 0.45 |
| 3 | LOC | Yes | 0.87 |
| | | No | 0.13 |
| 4 | MF | Good | 0.30 |
| | | Bad | 0.70 |
| 5 | LCN | Yes | 0.02 |
| | | No | 0.98 |
| 6 | RTV | Yes | 0.04 |
| | | No | 0.96 |
| 7 | ROB | Yes | 0.014 |
| | | No | 0.99 |

Table 6: Conditional probabilities of the child node (road traffic accident) given the states of the parent nodes (road traffic accident hazards)

| Road traffic accident hazards | | | | | | | | Conditional probability for road traffic accident | |
|---|---|---|---|---|---|---|---|---|---|
| S/N | CD | MF | LC | ROB | SPV | LOC | RTV | YES | NO |
| 1. | Yes | Good | No | Yes | Yes | Yes | Yes | 0.95 | 0.05 |
| 2. | Yes | Good | No | Yes | Yes | Yes | No | 0.92 | 0.08 |
| 3. | Yes | Good | No | Yes | Yes | No | Yes | 0.96 | 0.04 |
| 4. | Yes | Good | No | Yes | Yes | No | No | 0.65 | 0.35 |
| 5. | Yes | Good | No | Yes | No | Yes | Yes | 0.95 | 0.05 |
| 6. | Yes | Good | No | Yes | No | Yes | No | 0.40 | 0.60 |
| 7. | Yes | Good | No | Yes | No | No | Yes | 0.45 | 0.55 |
| 8. | Yes | Good | No | Yes | No | No | No | 0.20 | 0.80 |
| 9. | Yes | Good | No | No | Yes | Yes | Yes | 0.90 | 0.10 |
| 10. | Yes | Good | No | No | Yes | Yes | No | 0.85 | 0.15 |
| 11. | Yes | Good | No | No | Yes | No | Yes | 0.75 | 0.25 |
| 12. | Yes | Good | No | No | Yes | No | No | 0.64 | 0.36 |
| 13. | Yes | Good | No | No | No | Yes | Yes | 0.80 | 0.20 |
| 14. | Yes | Good | No | No | No | Yes | No | 0.39 | 0.61 |
| 15. | Yes | Good | No | No | No | No | Yes | 0.42 | 0.58 |
| 16. | Yes | Good | No | No | No | No | No | 0.15 | 0.85 |
| 17. | Yes | Good | Yes | Yes | Yes | Yes | Yes | 0.99 | 0.01 |
| 18. | Yes | Good | Yes | Yes | Yes | Yes | No | 0.97 | 0.03 |
| 19. | Yes | Good | Yes | Yes | Yes | No | Yes | 0.98 | 0.02 |
| 20. | Yes | Good | Yes | Yes | Yes | No | No | 0.90 | 0.10 |
| 21. | Yes | Good | Yes | Yes | No | Yes | Yes | 0.85 | 0.15 |
| 22. | Yes | Good | Yes | Yes | No | Yes | No | 0.82 | 0.18 |
| 23. | Yes | Good | Yes | Yes | No | No | Yes | 0.51 | 0.49 |
| 24. | Yes | Good | Yes | Yes | No | No | No | 0.48 | 0.52 |
| 25. | Yes | Good | Yes | No | Yes | Yes | Yes | 0.98 | 0.02 |
| 26. | Yes | Good | Yes | No | Yes | No | Yes | 0.97 | 0.03 |
| 27. | Yes | Good | Yes | No | Yes | No | No | 0.89 | 0.11 |

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| S/N | CD | MF | LC | ROB | SPV | LOC | RTV | YES | NO |
|---|---|---|---|---|---|---|---|---|---|
| 28. | Yes | Good | Yes | No | No | Yes | Yes | 0.83 | 0.17 |
| 29. | Yes | Good | Yes | No | No | Yes | No | 0.80 | 0.20 |
| 30. | Yes | Good | Yes | No | No | No | Yes | 0.49 | 0.51 |
| 31. | Yes | Good | Yes | No | No | No | No | 0.35 | 0.65 |
| 32. | Yes | Bad | No | Yes | Yes | Yes | Yes | 0.99 | 0.01 |
| 33. | Yes | Bad | No | Yes | Yes | Yes | No | 0.98 | 0.02 |
| 34. | Yes | Bad | No | Yes | Yes | No | Yes | 0.96 | 0.04 |
| 35. | Yes | Bad | No | Yes | Yes | No | No | 0.95 | 0.05 |
| 36. | Yes | Bad | No | Yes | No | Yes | Yes | 0.85 | 0.15 |
| 37. | Yes | Bad | No | Yes | No | Yes | No | 0.83 | 0.17 |
| 38. | Yes | Bad | No | Yes | No | No | Yes | 0.81 | 0.19 |
| 39. | Yes | Bad | No | Yes | No | No | No | 0.60 | 0.40 |
| 40. | Yes | Bad | No | No | Yes | Yes | Yes | 0.70 | 0.30 |
| 41. | Yes | Bad | No | No | Yes | Yes | No | 0.60 | 0.40 |
| 42. | Yes | Bad | No | No | Yes | No | Yes | 0.60 | 0.40 |
| 43. | Yes | Bad | No | No | Yes | No | No | 0.50 | 0.50 |
| 44. | Yes | Bad | No | No | No | Yes | Yes | 0.40 | 0.60 |
| 45. | Yes | Bad | No | No | No | Yes | No | 0.50 | 0.50 |
| 46. | Yes | Bad | No | No | No | No | Yes | 0.40 | 0.60 |
| 47. | Yes | Bad | No | No | No | No | No | 0.30 | 0.70 |
| 48. | Yes | Bad | Yes | Yes | Yes | Yes | Yes | 0.99 | 0.01 |
| 49. | Yes | Bad | Yes | Yes | Yes | Yes | No | 0.98 | 0.02 |
| 50. | Yes | Bad | Yes | Yes | Yes | No | Yes | 0.80 | 0.20 |
| 51. | Yes | Bad | Yes | Yes | Yes | No | No | 0.80 | 0.20 |
| 52. | Yes | Bad | Yes | Yes | No | Yes | Yes | 0.80 | 0.80 |
| 53. | Yes | Bad | Yes | Yes | No | Yes | No | 0.75 | 0.25 |
| 54. | Yes | Bad | Yes | Yes | No | No | Yes | 0.70 | 0.30 |
| 55. | Yes | Bad | Yes | Yes | No | No | No | 0.70 | 0.30 |
| 56. | Yes | Bad | Yes | No | Yes | Yes | No | 0.70 | 0.30 |
| 57. | Yes | Bad | Yes | No | Yes | No | Yes | 0.80 | 0.20 |
| 58. | Yes | Bad | Yes | No | Yes | No | No | 0.85 | 0.15 |
| 59. | Yes | Bad | Yes | No | No | Yes | Yes | 0.60 | 0.40 |
| 60. | Yes | Bad | Yes | No | No | Yes | No | 0.60 | 0.40 |
| 61. | Yes | Bad | Yes | No | No | No | Yes | 0.55 | 0.45 |
| 62. | Yes | Bad | Yes | No | No | No | No | 0.50 | 0.50 |
| 63. | No | Good | No | Yes | Yes | Yes | Yes | 0.40 | 0.60 |
| 64. | No | Good | No | Yes | Yes | Yes | No | 0.50 | 0.50 |
| 65. | No | Good | No | Yes | Yes | No | Yes | 0.20 | 0.80 |
| 66. | No | Good | No | Yes | Yes | No | No | 0.30 | 0.70 |
| 67. | No | Good | No | Yes | No | Yes | Yes | 0.25 | 0.75 |
| 68. | No | Good | No | Yes | No | Yes | No | 0.30 | 0.70 |
| 69. | No | Good | No | Yes | No | No | Yes | 0.40 | 0.60 |
| 70. | No | Good | No | Yes | No | No | No | 0.60 | 0.40 |
| 71. | No | Good | No | No | Yes | Yes | Yes | 0.80 | 0.20 |
| 72. | No | Good | No | No | Yes | Yes | No | 0.80 | 0.20 |
| 73. | No | Good | No | No | Yes | No | Yes | 0.61 | 0.39 |

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| S/N | CD | MF | LC | ROB | SPV | LOC | RTV | YES | NO |
|---|---|---|---|---|---|---|---|---|---|
| 74. | No | Good | No | No | Yes | No | No | 0.60 | 0.40 |
| 75. | No | Good | No | No | No | Yes | Yes | 0.49 | 0.51 |
| 76. | No | Good | No | No | No | Yes | No | 0.40 | 0.60 |
| 77. | No | Good | No | No | No | No | Yes | 0.40 | 0.60 |
| 78. | No | Good | No | No | No | No | No | 0.01 | 0.99 |
| 79. | No | Good | Yes | Yes | Yes | Yes | Yes | 0.99 | 0.01 |
| 80. | No | Good | Yes | Yes | Yes | Yes | No | 0.95 | 0.05 |
| 81. | No | Good | Yes | Yes | Yes | No | Yes | 0.85 | 0.15 |
| 82. | No | Good | Yes | Yes | Yes | No | No | 0.80 | 0.20 |
| 83. | No | Good | Yes | Yes | No | Yes | Yes | 0.75 | 0.25 |
| 84. | No | Good | Yes | Yes | No | Yes | No | 0.73 | 0.27 |
| 85. | No | Good | Yes | Yes | No | No | Yes | 0.60 | 0.40 |
| 86. | No | Good | Yes | No | Yes | Yes | Yes | 0.70 | 0.30 |
| 87. | No | Good | Yes | No | Yes | Yes | No | 0.68 | 0.32 |
| 88. | No | Good | Yes | No | Yes | No | Yes | 0.69 | 0.31 |
| 89. | No | Good | Yes | No | Yes | No | No | 0.65 | 0.35 |
| 90. | No | Good | Yes | No | No | Yes | Yes | 0.70 | 0.30 |
| 91. | No | Good | Yes | No | No | Yes | No | 0.65 | 0.35 |
| 92. | No | Good | Yes | No | No | No | Yes | 0.66 | 0.34 |
| 93. | No | Good | Yes | No | No | No | No | 0.60 | 0.40 |
| 94. | No | Bad | No | Yes | Yes | Yes | Yes | 0.98 | 0.02 |
| 95. | No | Bad | No | Yes | Yes | Yes | No | 0.95 | 0.05 |
| 96. | No | Bad | No | Yes | Yes | No | Yes | 0.95 | 0.05 |
| 97. | No | Bad | No | Yes | Yes | No | No | 0.80 | 0.20 |
| 98. | No | Bad | No | Yes | No | Yes | Yes | 0.80 | 0.20 |
| 99. | No | Bad | No | Yes | No | Yes | No | 0.78 | 0.22 |
| 100. | No | Bad | No | Yes | No | No | Yes | 0.79 | 0.21 |
| 101. | No | Bad | No | Yes | No | No | No | 0.50 | 0.50 |
| 102. | No | Bad | No | No | Yes | Yes | Yes | 0.70 | 0.30 |
| 103. | No | Bad | No | No | Yes | Yes | No | 0.67 | 0.33 |
| 104. | No | Bad | No | No | Yes | No | Yes | 0.69 | 0.31 |
| 105. | No | Bad | No | No | Yes | No | No | 0.55 | 0.45 |
| 106. | No | Bad | No | No | No | Yes | Yes | 0.60 | 0.40 |
| 107. | No | Bad | No | No | No | Yes | No | 0.59 | 0.41 |
| 108. | No | Bad | No | No | No | No | Yes | 0.59 | 0.41 |
| 109. | No | Bad | No | No | No | No | No | 0.55 | 0.45 |
| 110. | No | Bad | Yes | Yes | Yes | Yes | Yes | 0.80 | 0.20 |
| 111. | No | Bad | Yes | Yes | Yes | Yes | No | 0.78 | 0.22 |
| 112. | No | Bad | Yes | Yes | Yes | No | Yes | 0.79 | 0.21 |
| 113. | No | Bad | Yes | Yes | Yes | No | No | 0.65 | 0.35 |
| 114. | No | Bad | Yes | Yes | No | Yes | Yes | 0.85 | 0.15 |
| 115. | No | Bad | Yes | Yes | No | Yes | No | 0.83 | 0.17 |
| 116. | No | Bad | Yes | Yes | No | No | No | 0.60 | 0.40 |
| 117. | No | Bad | Yes | No | Yes | Yes | Yes | 0.85 | 0.15 |
| 118. | No | Bad | Yes | No | Yes | Yes | No | 0.80 | 0.20 |
| 119. | No | Bad | Yes | No | Yes | No | Yes | 0.83 | 0.17 |

| S/N | CD | MF | LC | ROB | SPV | LOC | RTV | YES | NO |
|---|---|---|---|---|---|---|---|---|---|
| 120. | No | Bad | Yes | No | Yes | No | No | 0.79 | 0.21 |
| 121. | No | Bad | Yes | No | No | Yes | Yes | 0.70 | 0.30 |
| 122. | No | Bad | Yes | No | No | Yes | No | 0.69 | 0.31 |
| 123. | No | Bad | Yes | No | No | No | Yes | 0.70 | 0.30 |
| 124. | No | Bad | Yes | No | No | No | No | 0.50 | 0.50 |

### 3.4. Bayesian Network Inference

Bayesian probability expression for the probability of occurrence of road traffic accident (Equation 2) was developed and solved using a Bayesian Excel worksheet. The probability of RTA (YES) is 0.59.

### 3.5. Bayesian Network Diagnostic Inference

Diagnostic inference is probabilistic inference of drawing a cause from conclusion, and is bottom up inference (Akinyemi and Adebiyi, 2016). The objective of this is to obtain the probability of occurrence of hazards causing particular states**.** For example, if road traffic accidents occur and it is requested to inference the degree to which this unexpected event magnitude was related to the state of road traffic accidents hazards i.e. the parent nodes; Bayesian diagnostic inference is carried out. Bayesian diagnostic inference determines the posterior probability of parent node. Therefore, the posterior probability for a parent node; say Speed Violation is Yes being given by:

$$\mathrm{P(SPV = Yes|RA = Yes)} = \frac{P(SPV{=}Yes) \times P\ (RA = Yes)}{Joint\ probability} \tag{3}$$

Mathematically:

$$\mathrm{P(SPV = Yes|RA = Yes)} = \frac{P(SPV = Yes) \times P(W_i)}{\sum P(H_j)} \tag{4}$$

Where: P (SPV =Yes | RA =Yes) = posterior probability that there is speed violation given that road traffic accident is Yes, P (SPV) = prior probability of SPV (parent node), $\sum$P ($H_j$) = Joint probability (i.e. the product of prior probability of child node and the conditional probability of the parent node.

From Equations 3 and 4, a Microsoft excel sheet was developed to determine the value of the posterior probabilities of parent nodes. The posterior probabilities of road traffic accident hazards are as follow:

$P(SPV = Yes|RA = YES) = 0.6375$
$P(CD = Yes|RA = YES) = 0.6375$
$P(MF = Bad|RA = YES) = 0.7705$
$P(LC = Yes|RA = YES) = 0.9714$
$P(ROB = Yes|RA = YES) = 0.0143$
$P(LOC = Yes|RA = YES) = 0.9059$
$P(RTV = Yes|RA = YES) = 0.9434$

Comparing posterior probability with prior probability (Table 4), it can be noted that there are some changes in the probability of occurrence of parent nodes when road traffic accident is observed. The percentage change is shown in Table 7. In Table 7, it is shown that there are significant changes in the probability of SPV =Yes, CD = Yes, MF = Bad, LCN =Yes, ROB = Yes, LOC = Yes, RTV = Yes (increased by 15.9%, 15.9%, 156.8%, 4757.5%, 43%, 4.13%, 2257% respectively) when road accident is Yes. This implies that road traffic accident is sensitive to the parent nodes: speed violation, careless driving, mechanical factor, road obstruction, loss of control, route violation and the most influential causal factor is the lack of concentration i.e. once road traffic accident occurs, it is more likely that lack of concentration, speed violation, careless driving, mechanical factor, road obstruction, route violation are the main causal factors.

Table 7: The change rate comparing prior probability with posterior probability

| Variable state | SPV =Yes | CD =Yes | LOC =Yes | MF = Bad | LCN = Yes | RTV =Yes | ROB = Yes |
|---|---|---|---|---|---|---|---|
| Prior probability | 0.55 | 0.55 | 0.87 | 0.3 | 0.02 | 0.04 | 0.01 |
| Posterior probability | 0.6375 | 0.6375 | 0.9059 | 0.7705 | 0.9715 | 0.9434 | 0.0143 |
| Change rate % | 15.9% | 15.9% | 4.13% | 156.8% | 4757.5% | 2257% | 43% |

The contributory effect of loss of control is the least with change rate of 4.13%. However, it should be noted that the posterior probability and prior probability for speed violation, careless driving and loss of control are still significant in causing road traffic accident irrespective of the change rate obtained for them. From the above analysis, it is obvious that a strict regulation should be made against route violation and lack of concentration (e.g. talking while driving, use of cell phones etc.). The results of this research will be useful in advising road safety agency on the likelihood of road traffic accidents occurrence and the indicators to road safety preventive strategies.

## 4. CONCLUSION

Road traffic accidents cause serious threat to human life worldwide. This study attempted to identify road traffic accident hazards and modeled (probabilistically) the occurrence of road traffic accident. Bayesian probability of road traffic accident occurrence obtained was 0.59. Bayesian diagnostic inference showed that speed violation, careless driving, mechanical factor, lack of concentration, road obstruction, loss of control and route violation are road traffic accident hazards that contributes to road traffic accident. The hazards with the greatest contribution to road traffic accident using fault tree analysis were sleeping on steering, overloading, bad road, mechanical deficient vehicle, road obstruction, dangerous driving, tyre burst, break failure and wrong overtaking. Loss of control contributes less to the system risk. The probability of road traffic accident occurrence using fault tree analysis was 0.73. The research has pointed out safety issues for road safety agency to concentrate upon for implementation of effective road safety programmes.

## 5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and contributions of Federal Road Safety Corps, Ogun State Command toward the success of this work.

## 6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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