Eliciting a mathematical model from the traffic safety index to estimate the number of road traffic accidents

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Abstract. Traffic accidents have become one of the most important problems experienced by countries, leading to the death or injury of many people and the waste of money, which is supposed to be spent on developmental and economic projects that benefit the entire society. In Iraq with the absence of suitable recording system of (Iraqi Roads Traffic Accident Data) and the lack in the measure of highway safety. Thus, lead to error in the analysis of traffic accidents. The aim of this study is to estimate Road Safety Index value and developing a model related it with Road Traffic Accident. To reach the research aim, parameters of Roadway, traffic, Roadside, Pavement and Miscellaneous, characteristics of ten cities in central and southern Iraq (Baghdad, Babylon, Karbala, Najaf, Qadissiya, Muthanna, Dhi Qar, Wasit, Maysan and Basra) were studied. The results show that the extra increase of Road Traffic Accident can be represented by negative exponential trend in relation with Road Safety Index, at 0.05 level of significance 87.6% of variation in Road Safety Index can be accounted for by exponential relationship with Road Traffic Accident.

Key Word: Traffic Safety; Traffic Accident; Road Safety Index; Level of Service.

1. Introduction

Traffic accidents have become one of the major daily concerns that threaten the lives of people and increase their fatalities annually. In developing countries, 85% of 1.25 million people die each year due to the Road Traffic Accident (RTA), and Iraq is ranked 18th out of the 180 countries in the total number of deaths due to traffic accidents according to the WHO report 2015.

All counties suffer from the road accident problem. Because countries vary widely in their road safety systems experiences and development levels, the magnitude of the problem is changed from one country to another. Majority of road injuries and deaths happen typically in developing and transitional countries according to [1]. ETSC explain that any measurement casually related to count accidents and fatalities or realize the process that leads to accidents, it is a safety performance indicator [2].

A number of researchers have studied the possibility of reducing the number of traffic accidents such as [3], NCHRP by adding protected / permitted LT phase, left turn phasing and displaced left turn lane the result show the percentage of reduction in number of traffic accident is 4-10, 23-48 and 48-85 in sequence [4]. [5] have shown that The World Health Organization [6] statistics almost 1.26 million people are killed in road accidents each year worldwide and an additional 50 million people are estimated injured. It is estimated they will become the world’s third leading cause of death by the year 2020 if no effective actions and efficient measures are taken.

Traffic safety is a complex issue where many of the factors that cause traffic accidents overlap, these factors have been studied by many researchers such as [7], studied the factors that aim to identify the elements that affect traffic safety: road design, environment, driver, vehicle, And the mutual relationship of each other.
[8] submitted a composite index, named a road safety development index (RSDI) containing three emphasis themes of the road safety domain these are: Product focus (fatality rates), People focus (road user behavior), and System focus (safer roads, safer vehicles, enforcement, socio-economic level and organizational performance). [9] Industrialized a Road Safety Index methodology (SPIs), dials with six risk domains these are: alcohol and drugs, protective systems, roads and trauma management, speed and vehicle. 21 European countries well studied at five weighting approaches were explored to combine the separate indicators into one overall index, which were: analytic hierarchy process, budget allocation, factor analysis, data envelopment analysis, and equal weighting.

[10] proposed the hierarchical fuzzy TOPSIS effectiveness method. In the application case, it shows the high correlation between the number of road fatalities per million inhabitants and derived composite index. Furthermore, [11] study of 28 European countries combination between risk indicators and a hierarchy of safety performance indicators for the sake of meaningful road safety benchmarking. 0.34-0.70 Road Safety Index developed by [12] for different type of roads in Bengaluru. [13] Study how to reduce number of RTA by suggesting an Expert system for RTA that affords expert discussion in the area of highway safety in Iraq. Finally Table 1 listed number of studies deals with traffic accident by developing modeled to road traffic accident (number or severity) and road traffic safety index.

### Table 1. Summary of Previous Studies Developing Models for Traffic Safety

| Author | Year | Developed model | Description |
|--------|------|-----------------|-------------|
| Smeed | 1949 | \( F = \frac{F}{V} = a(F)^{\beta} \) | \( F \): number of fatalities in road accidents in the country |
|       |      | \( V \): number of vehicles in the country |
|       |      | \( P \): population |
|       |      | \( a = 0.003, \beta = \frac{2}{3} \) |
|       |      | \( Ft \): is the number of fatalities for some country in a year t, |
|       |      | \( Vt \): is the number of vehicle kilometers travelled in that year, |
|       |      | \( \alpha, \beta \): are constants |
|       |      | \( Ft \): is the number of fatalities for a country in a year t, |
|       |      | \( Vt \): is the number of vehicle kilometers travelled in the year t, |
|       |      | \( V_{max} \): is the maximum number of vehicle kilometers, |
|       |      | \( K \): is the time lag in years, and |
|       |      | \( x, w, z, y, and c \): are constants |
|       |      | \( M_0 \): is the value of motorization at maximum personal risk, |
|       |      | \( T_t \): is the point where the exponential curve meets the T-axis, |
|       |      | \( T \): is the traffic risk, fatalities per number of vehicles, and |
|       |      | \( M \): is the motorization, vehicles per population |
|       |      | \( R \): is the risk of particular factor kilometers is the exposure in traffic, |
|       |      | \( W \): is the weight of the risk factor in a particular country |
|       |      | \( wi \): the weights of the Xi |
|       |      | \( Xi \): normalized indicators for country i |
|       |      | In most approaches \( \sum_{i=1}^{n} w_i = 1 \) and ranged from 0 to 1 |

2. Data Collection

For the purpose of reaching the aim of the search the data of Road Traffic Accidents (RTA) in Iraq from the ministry of planning - Central Statistical Organization (CSO) at 2010 was taken for the cities of central and southern Iraq and depending on the type of incident. Table 2 lists the distribution of these accident.
### Table 2. Number of Accidents Recorded According to the City and the Nature of the Accident

| City     | Crash | Coup | Runover | Other | Total |
|----------|-------|------|---------|-------|-------|
| Baghdad  | 593   | 130  | 730     | 0     | 1453  |
| Babylon  | 553   | 126  | 586     | 3     | 1268  |
| Karbala  | 117   | 17   | 232     | 9     | 375   |
| Najaf    | 675   | 57   | 425     | 6     | 1163  |
| Qadissiya| 332   | 112  | 419     | 55    | 918   |
| Muthanna | 153   | 83   | 73      | 0     | 309   |
| Dhi Qar  | 304   | 80   | 237     | 0     | 621   |
| Wasit    | 155   | 93   | 75      | 1     | 324   |
| Maysan   | 62    | 33   | 72      | 10    | 177   |
| Basra    | 483   | 62   | 420     | 0     | 965   |

### 3. Methodology (Road Safety Index (RSI) Measurement)

It is a common practice that road traffic accidents are a problem that leads to death, injury or damage to property, and many people have no awareness of the magnitude of the problem. In many developing countries, people believe that driver error is the main cause of traffic accidents, ignoring many reasons and factors that contribute or increase the number and size of damage caused by road traffic accidents. On the other hand, many researchers indicated that increase the probability and severity of accidents occur by many factors that can be chosen as risk factors. To meet the requirement of this research,

a) Table 3 explained the five studied traffic engineering factors and it is weighted that can be effect on the RTA to estimate RSI using the same technique dependent by [12].

### Table 3. Characteristics and Weight of Traffic Engineering Factors

| Factors of Traffic Engineering Study | Parameters                          | Relative Weight |
|-------------------------------------|-------------------------------------|-----------------|
| Characteristics of Roadway          | Carriageway width                   | 0.34            |
|                                     | Number of intersections/km          |                 |
|                                     | Type of intersection                |                 |
|                                     | Speed                               |                 |
|                                     | On-street parking                   |                 |
| Characteristics of Traffic          | Road markings                       | 0.26            |
|                                     | Speed Breakers/km                   |                 |
|                                     | Number of Fatalities/km             |                 |
|                                     | Signs                               |                 |
| Characteristics of Roadside         | Presence of Obstacles               | 0.18            |
|                                     | Shoulder                            |                 |
|                                     | Street Lighting Interval            |                 |
| Characteristics of Pavement         | Pavement status                     | 0.13            |
|                                     | Potholes/km                         |                 |
| Characteristics of Miscellaneous    | Bus-stop distance from Intersection  | 0.09            |
|                                     | Intersection visibility             |                 |
|                                     | Presence of median                  |                 |

b) Apply this below equation to calculate RSI

c) \[ RSI = \frac{\sum_{i=1}^{n} W_i \times V_{ei}}{\sum_{i=1}^{n} W_i \times V_{si}} \] (1) [12].
Where:

N: number of Traffic Engineering Characteristics Study;
Wi: relative weightage to each Traffic Engineering Characteristics Study;
Veᵢ: service characteristics score for existing situation and
Vsᵢ: service characteristics value scores.

d) Checked the Calculated numerical scale of RSI suggested by [14] as shown in Table 4.

| RSI range       | Inadequate | Poor | Average | Good | Excellent |
|-----------------|------------|------|---------|------|-----------|
| RSI Rating      | Less than 20% | 20-40% | 40-60% | 60-80% | More than 80% |
| 10%             | 30%        | 50%  | 70%     | 90%  |

e) Checked the Level of Service (LOS) based on calculated numerical scale of RSI suggested by [8] as shown in Table 5.

| RSI %          | LOS         |   |   |   |   |
|----------------|-------------|---|---|---|---|
| 0.80-1.00      | Excellent   |   |   |   |   |
| 0.60-0.80      | Very Good   |   |   |   |   |
| 0.40-0.60      | Good/Average|   |   |   |   |
| 0.20-0.40      | Poor        |   |   |   |   |
| 0.00-0.20      | Very Poor   |   |   |   |   |

4. Case Study

In order to reach the objective of the research, sections of the road network of ten cities in central and southern Iraq (Baghdad, Babylon, Karbala, Najaf, Qadissiya, Muthanna, Dhi Qar, Wasit, Maysan and Basra) were studied.

5. Result

Table 6 to Table 8 illustrated the average score of all studied parameters of traffic characteristic for three of the case study as an example, as well as these Tables describe the value of RSI, on the other hand Table 9 explained the finale results of RSI and LOS for the studied cities.
### Table 6. Traffic Characteristics and Score Value for Road network in Baghdad City

| Factors of Traffic Engineering Study | Parameters                              | Data Observing                              | Score | Average Score | RSI  |
|-------------------------------------|-----------------------------------------|---------------------------------------------|-------|---------------|------|
|                                     | Carriageway width                       | 2 lane with median                          | 35    | 30            | 31.67|
| Characteristics of Roadway          | Number of intersections/km              | 2                                            | 30    |               |      |
|                                     | Type of intersection                    | Right angle                                 | 30    |               |      |
|                                     | Speed                                   | 85% more than limit                         | 20    |               |      |
|                                     | On- street parking                      | Valid                                        | 10    |               |      |
|                                     |                                        | Edge, Lane, Center line, Stop and Zebra Crossing marking | 30    |               | 31.67|
| Characteristics of Traffic          | Road markings                           |                                             |       |               | 0.38 |
|                                     | Speed Breakers/km                       | 4                                            | 30    |               |      |
|                                     | Number of Fatalities/km                 | Serues Damage                               | 45    |               |      |
|                                     | Signs                                   | N.A.S*                                      | 55    |               |      |
| Characteristics of Roadside         | Presence of Obstacles                   | Tree, Billboards and road users distractive  | 50    |               | 51.67|
|                                     | Shoulder                                | N.A.S*                                      | 50    |               |      |
|                                     | Street Lighting Interval                | 50m                                          | 55    |               |      |
| Characteristics of Pavement         | Pavement status                         | Average                                     | 45    |               |      |
|                                     | Potholes/km                             | 8                                            | 40    |               |      |
|                                     | Bus-stop distance from Intersection     | 20m                                          | 50    |               |      |
| Characteristics of Miscellaneous    | Presence of median                      | 25cm height                                 | 55    |               |      |
|                                     | Intersection visibility                 | Good                                         | 40    |               | 48.33|
|                                     | Presence of median                      | 25cm height                                 | 55    |               |      |

N.A.S: No adequate signs; RSI: Road Safety Index

### Table 7. Traffic Characteristics and Score Value for Road network in Babylon City

| Factors of Traffic Engineering Study | Parameters                              | Data Observing                              | Score | Average Score | RSI  |
|-------------------------------------|-----------------------------------------|---------------------------------------------|-------|---------------|------|
|                                     | Carriageway width                       | 2 lane with median                          | 65    |               | 53.33|
| Characteristics of Roadway          | Number of intersections/km              | 3                                            | 40    |               |      |
|                                     | Type of intersection                    | Four – leg & Three Leg                      | 55    |               |      |
|                                     | Speed                                   | 75% more than limit                         | 57    |               |      |
|                                     | On- street parking                      | Valid                                        | 30    |               |      |
|                                     |                                        | Edge, Lane, Center line, Stop and Zebra Crossing marking | 10    |               | 39.5 |
| Characteristics of Traffic          | Road markings                           |                                             |       |               | 0.51 |
|                                     | Speed Breakers/km                       | 5                                            | 45    |               |      |
|                                     | Number of Fatalities/km                 | Fatality & Injury                           | 55    |               |      |
|                                     | Signs                                   | N.A.S*                                      | 40    |               |      |
| Characteristics of Roadside         | Presence of Obstacles                   | Tree, Billboards and road users distractive  | 66    |               | 67.33|
|                                     | Shoulder                                | N.A.S*                                      | 86    |               |      |
|                                     | Street Lighting Interval                | 30m                                          | 50    |               |      |
| Characteristics of Pavement         | Pavement status                         | Average                                     | 50    |               | 42.5 |
|                                     | Potholes/km                             | 10                                           | 35    |               |      |
| Characteristics of Miscellaneous    | Bus-stop distance from Intersection     | 40m                                          | 45    |               | 54.33|
|                                     | Intersection                           | Good                                         | 63    |               |      |
|                                     | Presence of median                      | 10cm height                                 | 55    |               |      |

*N.A.S: No adequate signs; RSI: Road Safety Index*
Table 8. Traffic Characteristics and Score Value for Road network in Karbala City

| Factors of Traffic Engineering Study | Parameters                    | Data Observing                      | Score | Average Score | RSI  |
|--------------------------------------|-------------------------------|-------------------------------------|-------|---------------|------|
| Characteristics of Roadway           | Carriageway width             | 2 lane with median                  | 60    | 48.33         |      |
|                                      | Number of intersections/km    | 4                                   | 35    |               |      |
|                                      | Type of intersection          | Four – leg & Three Leg              | 50    |               |      |
|                                      | Speed                         | 35% more than limit                 | 33    |               |      |
|                                      | On-street parking             | Valid                               | 15    |               |      |
| Characteristics of Traffic           | Road markings                 | Edge, Lane, Center line, Stop and Zebra Crossing marking | 5     | 28.5          | 0.40 |
|                                      | Speed Breakers/km             | 3                                   | 40    |               |      |
|                                      | Number of Fatalities/km       | Fatality & Injury                   | 50    |               |      |
|                                      | Signs                         | N.A.S*                              | 28    |               |      |
| Characteristics of Roadside          | Presence of Obstacles         | Tree, Billboards and road users distractive | 41    |               |      |
|                                      | Shoulder                      | N.A.S*                              | 56    | 45.67         |      |
|                                      | Street Lighting Interval      | 20m                                 | 40    |               |      |
| Characteristics of Pavement          | Pavement status               | Average                             | 36    | 30.5          |      |
|                                      | Potholes/km                   | 10                                  | 25    |               |      |
| Characteristics of Miscellaneous     | Bus-stop distance from        | 20m                                 | 34    |               |      |
|                                      | Intersection visibility       | Poor                                | 50    | 41.67         |      |
|                                      | Presence of median            | 20cm height                         | 41    |               |      |

*N.A.S: No adequate signs; RSI: Road Safety Index

Table 9. Summery of Results

| City     | RTA | RSI | LOS   |
|----------|-----|-----|-------|
| Baghdad  | 1453| 0.28| Poor  |
| Babylon  | 1268| 0.30| Poor  |
| Karbala  | 375 | 0.48| Good  |
| Najaf    | 1163| 0.34| Poor  |
| Qadissiya| 918 | 0.43| Good  |
| Muthanna | 309 | 0.57| Good  |
| Dhi Qar  | 621 | 0.42| Good  |
| Wasit    | 324 | 0.51| Good  |
| Maysan   | 177 | 0.68| Very Good |
| Basra    | 965 | 0.38| Poor  |

5.1. Relationship between RTA and RSI

Figure 1 shows that an exponential relation explains increasing variation (87.6 %) of Road Traffic Accident in relation with Road Safety Index.
5.2. Developed Regression Model Relate RTA with RSI

The following regression model was developed by STATISCA software according to the data summarized in Table 9.

\[
RTA = 7222.8e^{-5.609RSI} \quad R^2 = 0.876 \quad 0.28 \leq RSI \leq 0.68 \quad (2)
\]

Where:
RTA: Road Traffic Accident.
RSI: Road Safety Index.

Table 10 explained the statistical model Parameters.

|          | R     | R²    | F sig. | Stand. Error | P-value Intercept | P-value RSI |
|----------|-------|-------|--------|--------------|------------------|-------------|
| Intercept| 0.936 | 0.876 | 7.94E-05| 173.4276     | 5.11E-06        | 7.94E-05    |

Referring to Table 10, it can be seen that 87.6% of variation in Road Safety Index can be accounted for by exponential relationship with Road Traffic Accident at 0.05 level of significance.

6. Conclusions

The search results agree with the search results [8], [12] and [(13]. By the results it is found RSI is highly affected by the Traffic, Roadside, Pavement and Miscellaneous characteristics.

Statistical model is developed using exponential regression technique to correlate RTA with RSI. The proposed model for RTA has explanation variation of 87.6 at 5 percent level of significance.

Developed model related RTA with RSI show that: RTA increase when RSI decrease.
Interaction between traffic offices, hospitals and engineers is required to obtain accurate and sufficient results to be adopted to achieve or develop traffic safety.

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