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Development of Road Safety Index (RSI) Under Mixed Traffic Condition Using Analytic Hierarchy Process

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Abstract

The assessment of road safety is conducted through various indicators. Unfortunately, many individuals do not fully grasp the severity of this issue. Often, their understanding is hindered by the absence of clear metrics that effectively illustrate the extent of the problem. Consequently, there is a need for a road safety measurement tool. This study introduces a straightforward and comprehensible instrument known as Road Safety Index (RSI). The significance of the RSI lies in its ability to evaluate and highlight road safety achievements in an easily interpretable format, thereby facilitating an understanding of whether a road is deemed safe or unsafe, and indicating areas within a country or city that require attention regarding road safety. This study developed the RSI by utilizing several road safety indicators, which are categorized into three primary macro indicators: human factors, vehicle conditions, and road infrastructure. Data collection involved conducting interviews with drivers, inspecting road conditions, and analyzing traffic study data to ensure a reliable population sample. Additionally, documented data from the Arba Minch City Traffic Police and the Road & Transport Office, along with both published and unpublished materials from 2018 to 2022, were incorporated. The study employed a thorough data preparation process, including weighting and aggregation through Analytical Hierarchy Process (AHP) method, which involved creating a pairwise comparison matrix to establish the weight of each indicator and verify the consistency of the values. Furthermore, data normality was conducted using SPSS. The analysis revealed that the values generated by the tool, ranging from 0.6 to 0.8, indicated that the city's roads are in a safe condition, reflecting a very good level of service. The RSI also contributes to the development of a comprehensive catalog of macro-level metrics for diverse applications in road safety, offering an extensive overview of road safety performance. The research produced a practical and thorough instrument for assessing road safety performance, creating awareness of road safety concerns and offering a framework for focused enhancements in road safety within Arba Minch City. The study concluded that various road safety factors could be utilized to create a road safety index that represents the current condition of the roads as a single value.

Keywords: Road Safety, Analytical Hierarchy Process, Traffic, Safety Index, Safety Indicator

1. Introduction

Generally speaking, the safe and effective movement of people and goods is the aim of transportation. Designers employ a wide range of instruments and methods to accomplish this [1]. Analyzing the majority of indicators' consistency is one way to increase road safety. The costs of traffic accidents on a social, economic, and human level have made road safety a major global concern [2]. The problem of traffic accidents has been described in a number of ways, including the possibility that it is an indication of a social illness. Some argue that a developing country with a high percentage of youth in the population should have a higher death toll than a developed country with a lower birth rate and an older age group, even though young drivers worldwide carry a higher risk of being involved in accidents.

Nations that have a high percentage of motorbikes are particularly vulnerable on roadways ought to also experience a higher number of casualties than those where the majority of road users are well-protected within vehicles. In a similar vein, one may argue that wealthy nations are safer and/or healthier than impoverished nations since wealthy people have better infrastructure, access to hospitals and medical services [13].

1.1. Statement of Problem

There is a widespread belief in the public discourse regarding road safety that accidents that cause injury, death, or property damage are a concern. The sad truth is that a lot of people are unaware of how serious the issue is. Although many people, particularly in developing nations, believe that driver error is the primary cause of the issue, it is evident that there are other causes and factors that also play a role. They usually lack precise measurements that would allow them to see the scope of the issue in an easy-to-understand manner, which limits their comprehension. This information should also be based on easily understood statistical measures for drivers who wish to know the risks. Sadly, deaths rates (deaths per vehicle or per person) are the primary metric used to assess the severity of the road safety issue in a nation or city today. In some cases, measurements for these rates are not uniform, and they are frequently too complex for average people to understand [3].

Therefore, there is a need to develop a simple and easily understandable tool for road safety which is road safety index. Besides this, the selected study area has road safety problem as other cities of Ethiopia. The study area is a tourism city; for this reason the administrative body should be able to understand road safety problem, in inspiring, solving or reducing the problem and pay more attention for road safety due to attraction of tourism.

Thus, the study is crucial to investigate safety of road indicators for measure or identify the level of safety of road performance. It incorporate and summarizes vast knowledge and information about performance of indications of road safety that will be transformed into one specific, quantifiable value the index of road safety (RSI). Accordingly, the study aims to investigate indicators of road safety and build a comprehensive Index of Road Safety to fill the gap of knowledge on road safety [6].

1.2. Objective the study

1.2.1 General objective

The primary goal of this research was to development of road safety index (RSI) under mixed traffic condition using analytic hierarchy process methods.

1.2.2 Specific objectives

In an effort to meet the overall goal, the following specific objectives are set:

- Identify the possible indicators pertaining to road user risk factors, vehicle safety, and infrastructure
- Measure and combine different road safety indicators
- Create value scores and relative weightings for each index.

To pinpoint deficiencies in the system of road traffic and accurately represent the state of the road at present.

2. Literature Review

2.1 Problems of road safety

Safety on the road refers to the application of all traffic safety precautions to guard against and prevent collisions [4]. The primary determinants are three stages: the host, which is the human, the surroundings, which is the vehicle itself, as well as the surrounding traffic and infrastructure [5].

Human Behaviors

Encouraging driver behavior & performance is the main obstacle to increasing road safety. The following factors have been observed to be strongly connected to a higher danger of traffic accidents: young age, male gender, speed, substance exert an impact, use of a cell phone while driving, prior driving experience, disposition, attitude, masculine gender, and aggression, as well as stress, anxiety, emotionality, exhaustion, sleep deprivation, and negligence [8]. They can cause people to take dangerous "Shortcuts."[7]

Vehicle Safety

A vehicle's condition can be dangerous and raise the chance of a collision for a number of reasons. For instance, a car's engine, brakes, tires, gearbox, lights, or steering could all be malfunctioning, which could be extremely risky while driving [9]. Unfortunately, poor vehicle maintenance has contributed to numerous fatal collisions and crashes that have left victims permanently disabled and turned their lives upside down [10]. Manufacturers and safety analysts have long been concerned with the mass, size, and speed of vehicles [5].

The Quality of Infrastructure

Not all automobile accidents are the result of drivers. The truth is that about half of all car accidents occur on poorly maintained roads and highways [15]. An additional factor in accidents is poorly maintained roads. Some of the things that can harm cars and hurt their occupants are pot holes, uneven surfaces, broken concrete, road surface cracking, and even sinkholes [12].

2.2 Road safety indicators and Concept of road safety index (RSI)

Large volumes of information must be comprehensively represented by indicators, which also need to condense complexity into a single, understandable message. [13]. Advocates of composite indices contend that creating and utilizing them has a number of advantages:

- Perform better in making comparisons.
- Perform better when condensing intricate problems to one particular value. [14].
- When policymakers are too occupied to investigate specifics, they work most favorably to provide them with summaries of customized information.
- Are more effective at communicating with everyone in a straightforward manner. [17] [18].

Based on different studies, Road safety index (RSI) can be defined as a way of determining the degree of road security; it is a composite index, in which indicators

describing the road safety outcomes are combined into one figure.

3. Research Methdology

3.1 Research Design & Sampling Technique

The research was conducted in Arba Minch city's roadways. This study used a random sample technique based on vehicles registeration. Yamane (1967:886) provided the following formula, which was used to determine the sample size for this study. $n = \frac{N}{1+N(e^2)}$, Where n is sample size, N is population size &e= sampling error

Usually set at 1.96 (or a~2), a normal standard deviation corresponds to a 95% level of confidence. Percentage of the target population thought to possess a specific trait. In the absence of a plausible approximation, employ 50% (or 0.5) (the percentage of the target population lacking the specific attributes). d= required degree of accuracy, also known as margin of error, is typically set at the 0.05 level (sometimes at 2.0).

Table 1 Sampling Frame & Sampling Size

Types of vehicle	Sample frame of each types of vehicles (N1,N2$N3)	Sample size of each types of vehicles (n1,n2,n3…n8)
Two wheeler	5950	261
Bajaj	1925	84
Automobile	362	16
Min bus (Taxi)	165	7
Bus	81	3
Small truck	112	5
Medium truck	90	4
Large truck	45	2
Total	8730	382

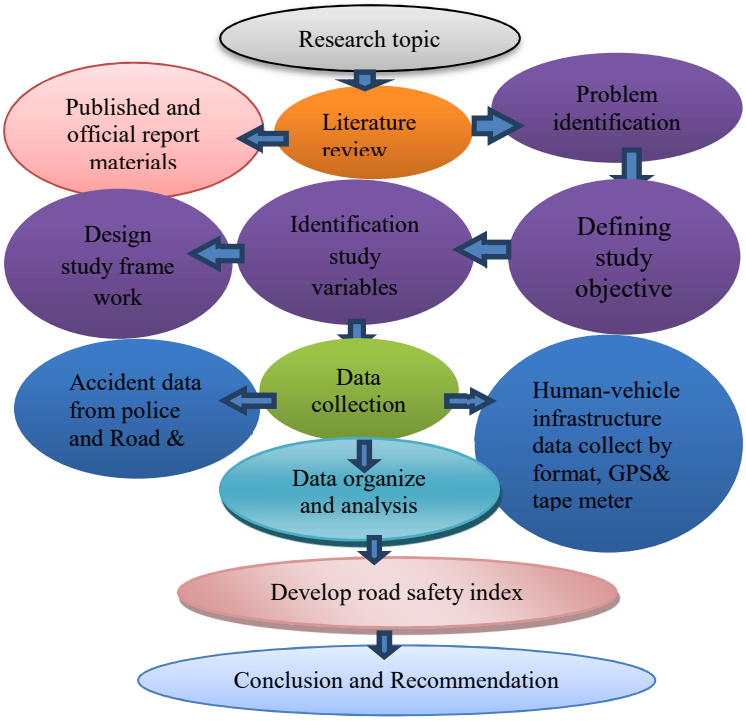


Figure 3-1 Research Design Approach and Conceptual Framework of the Study

3.2 Selecting Indicators

Selecting which indicators to include in an index is the first step in the process. This step was primarily guided by theory. Selecting the right indicators is a difficult task [11]. The advantages and disadvantages of each indicator can be used to determine which one to use for each risk domain.

A set of selection criteria can be used to list and assess potential indicators. Good roadway security indicators of performance should meet each of the following eight requirements,

– The indicator is **legitimate and applicable** to the goals of the policy. Also the indicator has an action focus and can be used to set a performance goal and the phenomenon is sufficiently depicted by the indicator for us to be able to quantify it. For example, the indicator number of accidents is legitimate and applicable to the goal of improving road

safety. It has an action focus as it can be used to set a performance goal of reducing the number of accidents. The phenomenon is sufficiently depicted by the indicator as it counting the numbers of accident.

- **Quantifiable**: the indicator can be objectively and quantitatively measured. For example, the number of cars produced in factory can be measured and recorded.
- **Comprehending:** the indication is well-defined and the indicator has a plausible and understandable meaning. For example, the indicator' average temperature' is well- defined and easy to understand.
- **Data availability:** data for a wide range of issues (in this case, nation) accessible in an appropriate span of time and at an affordable price. It is possible for the indicator to be current frequently. For example, the data on the number of accident should be available and updated regularly.
- **Reliable:** are the sources of the data credible and has a scientific approach been taken in gathering the data. For example, the data collected is considered reliable as it follows a scientific approach.
- **Comparable/ coherent:** the indicator is consistent both in space (do the subjects apply the same definition) and time (i.e., has the same definition, method, etc.).
- Is the **indicator specific**, meaning it targets a particular level also the indicator sufficiently detailed.
- The **indicator** is **sufficiently sensitive** to capture variations in risk over time. Minor adjustments show up in the value of another indicator [13].

3.3 Descriptions of Indicators

3.3.1 Dependent Variable

The majority of composite indices are structured using linear additive regression. Thus, may quantify every factor indicator separately and then combine all of the normalized proportions within a single index.

RSI = f (H, V, R) Where

H is the human-related factors; V is vehicle-related factors

R is road and its infrastructure factors

The dependent variable in the study's focus was safety on the road Status. In regards to analysis, the Road Safety Index (RSI) was used to grade the roads; the roads were categorized according to their level of safety.

The road is therefore rated as **Very Good, Excellent, Good/Average, Poor, and Very Poor**. The road grading according to the quality of service provided is displayed in the Table 2.

Table 2 Road grading according to RSI

Percentage of RSI	Service of livelily
0.80 to1	Excellent
0.60 to less than 0.80	Very Good
0.40 to less than 0.60	Good/Average
0.20 to less than 0.40	Poor
0.00 to less than 0.20	Very poor

Source (Road Safety Index and Evaluation Kushnappa B K,)

3.3.2 Independent Variables

Human related factor

There are different factors on human related factors or road user factors, generally classified into pedestrian behavior and driver behavior. As known for the time and financial constraints the study covers only driver

behaviors. According to the literature review more accidents occurred due to driver behaviors [2]. Also these micro indicators should be studied to deal with limited factors that are more exposés for road traffic problems such as using a seat belt, using helmet, the age of the driver, speeding, using alcohol/chat and using a mobile phone season of driving [16].

Vehicle Related

The other macro indicator was on vehicle factors. Vehicle safety means on the other hand the safety of roads. There are different indicators related to vehicles such as the size of the vehicle which is heaviness/bigness and lightness/smallness of the vehicle and the age of the Automobile flaws raise the possibility of having a crash. On the other hand, new cars have better protection against accidents, vehicle maintenance and technical conditions, vehicle types, vehicle compassion etc. From those factors, the study chose more reputable and accident-dominant lieder factors like age, size, and technical condition of the vehicles.

Road and Infrastructure Related

Safety of the road related to road infrastructure There are many indicators of road design and road construction. The geometric design of the road was the major indicator for road safety; un proper construction was the other factors A roadway's layout can increase the likelihood of accidents by making it harder to see or anticipate other cars, posing a risk to drivers through pinch points and other dangerous obstacles, and making the area more vulnerable to bad weather.. From those factors for the sake of cost and time select few indicators such as Road condition (paved or unpaved), on street parking, Visibility of intersection, and Traffic sign.

3.4 Method of Data Collection

The work is done on the site and the kind of information that was gathered based on the issue of road safety. Data was collected from data sources which are primary data and secondary data. Primarily data was field investigated and collected from the selected corridor of road and secondary data is collected from Arba Minch city traffic police report and Road and Transport office. The data will classify into two which are both primary and secondary.

Primary data

Primary data was traffic study and site observation; traffic study data was collected for road user/human-related factors and site observation for road and its infrastructure data. Traffic study data was collected by using a general method from Ariba Minch city selected road corridors. The city has two sub-cities; Secha and Sikela. Data was collected from those sub-city stretchees using enumerators. In these parts, different indicators are collected by preparing appropriate formats for both road user and infrastructure data. In road user data was collected by counting seat belt user for vehicle driver, helmet users for two wheeler drivers, and minimum age of the driver (below 18). And exceeding speed driver data collected by using general study method of speed study technic. For infrastructure data was collected the availability or location of traffic signs in available sites, provision of speed limit and on street parking.

For now the training of speed the study was also included. To collect the spot speed data of vehicles in a traffic stream; used two reference lines can be selected on the stretch of road that take 50 meters distance as two enumerators stand on the side of both reference lines. As soon as the vehicles crossed the reference lines, the enumerators

recorded the entry time and exit time of distinct kinds of automobiles respectively. The difference in time was given the travel time and hence the speeds can be determined. For the selected sample use the registration number of the vehicle to identify it from another vehicle; but for the sake of privacy use the identification code instead of registration numbers.

For the sake of this study, a number of road safety inspection checklists were examined, accepted, and altered. The components (indicators) of the checklist were designed to evaluate the level of road safety in the chosen network of the road. The safety of the section was examined using the itemized checklist. Every street segment in both regions was examined and every item on the list was verified. These data were gathered using inspection, counting, and measuring techniques without the use of any undeserving sample.

In the data collection time so many challenges faced, especially in primary data collection the weather condition is the first challenge the season was rainy time, shortage of budget is the other challenge, way of getting clear information from of selected people

Secondary data

Secondary data was collected from Ariba Minch city traffic police and road and transport office. The data are accident reports, number of vehicles registered distributed with age and technical approval level, and percentage of paved and unpaved main roads in the city. The data will be collected from the road and transport office and the traffic police office. This data only collected from mentioned areas by checking their ambiguity and reliability.

3.5 Method of Data Analysis Normalizing indicators

Normalization is one step that might be required; the goal is to make all the data similar. The indicators could introduce bias into the index because they could have different magnitudes, be expressed in different units, or show a lot of variation from the mean. This step of the RSI construction process is the normalization of the values of indicators before integrating them into RSI. The indicators have different scales and units. The idea of normalization makes all indicators acquire the same magnitude before mixing them.

Weighting & Aggregation method

Since an index is a weighted compilation of a number of indicators, it is imperative to give each indicator a proper weight, especially when varying numbers of indicators address different safety concerns. Weighting is a critical step in representing the relative importance of each indicator and its impact on the overall level of road safety.

Analytic Hierarchy Process

In the Analytic Hierarchy Process (AHP), weights are assigned by first creating a pairwise comparison matrix for each set of factors and then comparing them to one another based on their relative importance. The relative weights of the factors are obtained using the pairwise comparison matrix, and these weights are subsequently used to prioritize and make decisions according to their significance [19].

Step 1: Building a Hierarchy

Identifying the issue is the first step. Next, arrange each element in a hierarchy. The primary objective or goal is located at the top, and the alternatives that support the goal through intermediate attributions are located at the bottom.

Step 2: Comparing Pairwise

The next stage is to assess each set of criteria in pairs after the hierarchy has been established, and then the pairwise comparison matrices are created. Every matrix member is derived from the pairwise comparison procedure, which evaluates a pair of criteria or options through pairwise comparisons..

Table 2. Scale of relative importance

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate value
1/3, 1/5, 1/7, 1/9	Value of inverse compactions

Source (According to Thomas L. saaty 1980)

The lower diagonal is filled using this process, which is repeated for each of the criteria listed in the left column.

$$aij = \frac{1}{aj} \qquad (1)$$

Where a,ij is the element of row i column j of the matrix.

It is necessary to construct this pairwise comparison for every level of hierarchy. It denotes the construction of multiple matrices for criteria, sub-criteria, and alternatives. Keep in mind that before moving on to the next phase, the consistency of these matrices must be confirmed. When comparisons are consistent, it indicates that the scores assigned to each criterion are reasonable [19].

The consistency ratio (CR) is defined in [20] as follows:

$$\mathrm{CR} = \frac{CI}{RI} \qquad (2)$$

where CI is the consistency index and RI is a random index.
The value of CI is calculated by

$$\mathrm{CI} = (\lambda\mathrm{max} - \mathrm{n})/(\mathrm{n} - 1) \qquad (3)$$

Where λ_{max} is the maximum eigenvalue of the pairwise comparison matrix and n is a number of comparison objects.

Further information about CR computation is available in [20]. To accept the consistency of the matrix, the value of CR needs to be less than 0.1. If not, a portion of the component needs to be fixed.

Step 3: Eigenvector computation and ranking

Determining the eigenvector for the criteria and sub-criteria matrices is the third step. When determining the ranking of an alternative, the eigenvector—a vector of weighting factors—must be multiplied by each criterion and sub-criteria. One can obtain the eigenvectors from:

$$P \times v = \lambda v \qquad (4)$$

Where v is an eigenvector, λ is eigenvalue and

$$\mathrm{P} = \begin{bmatrix} 1 & 1/a1,2 & a1,2 & 1 & \cdots & a1N & a2N & \vdots \\ \vdots & 2 & \ddots & \vdots & 1/a1,N & a2N & \cdots & 1 \end{bmatrix} \qquad (5)$$

It is possible to compute v and λ using the numerical method. The weighting factor is contained in v, which can be either a vector or a column matrix.

$$\mathrm{V} = |w1\ w2\ \vdots\ w| \qquad (6)$$

Where w1 is the weight factor associated with the first criteria,

w2 is the weight factor associated with the second criteria & so on.

Finally, a decision matrix of the alternatives, denoted by Aj , of all the criteria combined is determined by the following equation.

$$Aj = \sum_{i=1}^{N} \quad ajWj \quad for\ i = 1,2, \ldots . M \qquad (7)$$

Where M is the number of alternatives and N is a number of criteria. Using the average of normalized value creating weights [19]

Step 4: Calculating the consistency

Consistency is computed in the Analytic Hierarchy Process (AHP) to guarantee the validity and reliability of the pairwise comparison matrix. The pairwise comparison matrix is regarded as consistent and dependable if the CR is less than 0.1.Because it guarantees that the pairwise comparison matrix appropriately reflects the decision-maker's preferences and assessments, calculating consistency is crucial. The weights obtained from the matrix might not fairly represent the decision-maker's preferences if it is inconsistent, leading to suboptimal decisions. The steps to calculate consistency in the AHP:

1. Determine the Consistency Index (CI): CI = (λmax - n) / (n - 1) is the formula used to calculate the consistency index. n is the number of criteria or factors being compared, and λmax is the maximum eigenvalue of the pairwise comparison matrix.

2. Find the random index (RI): Based on the size of the matrix, or the number of criteria, a table with predetermined values is used to generate the random index. When determining the expected degree of consistency for a random matrix, the RI is used as a benchmark.

3. Determine CR: Next, compute the consistency ratio using the formula CR = CI / RI. The pairwise comparison matrix is deemed sufficiently consistent if the CR is less than 0.1. [19].

Table 3 Standard values for random index

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	00	00	0.58	0.9	1.12	1.24	1.32	1.41
N	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
RI	1.45	1.49	1.51	1.54	1.56	1.57	1.58	

Source (According to saaty 1980)

Aggregation method

Pairwise comparisons are used to determine the weights for each factor, which are then ranked in decreasing order of importance to aggregate the indicators using the Analytic Hierarchy Process (AHP). Subsequently, the weights are employed to combine the distinct elements into a combined single index.

The following procedures can be used to determine the composite single index:

1. Multiply each factor's weight by the score or corresponding value.
2. Add up the products that were acquired for each factor in step 1.
3. Split the total that you got in step 2 by the sum of the weights of all the factors.

The composite single index, which shows the overall level of the construct being measured, is the outcome of step 3 [19].

4. Data Analysis & Presentation

4.1 Description of Traffic Accident

Among the total accidents occurred, 23.27% fatal, 28.16% severe injuries, 38.54 % slight, and 10.03% property damages. According to accident data the accident from year 2018 to 2020 the crash was decrease, from 2018 the crash was decreased by 39% on 2019, from 2019 the crash also decreased on 35% on

2020. But in the 2021 the accident was rapidly increased by 445% from 2020, on the last year of the study the accident was decreased by 75%.

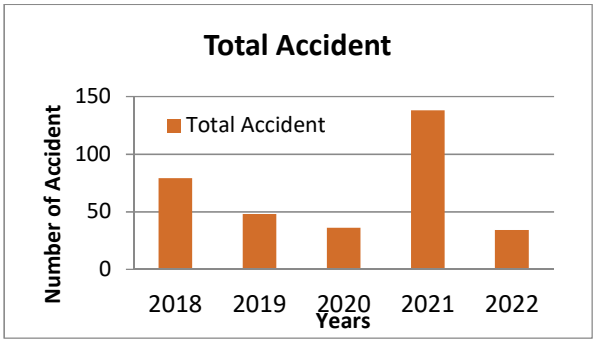


Figure 1 Accident distribution per year

The yearly variation in accident severity over the entire stretch of 2018–2022 is displayed in the chart below. The severity of accidents had decreased. It was caused by a variety of factors, including a poor traffic environment, an increase in vehicle awareness

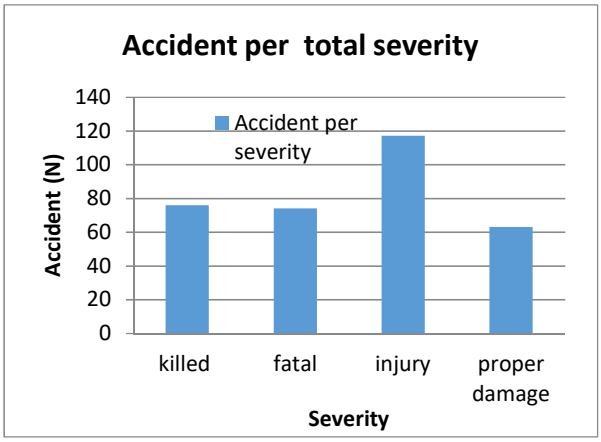
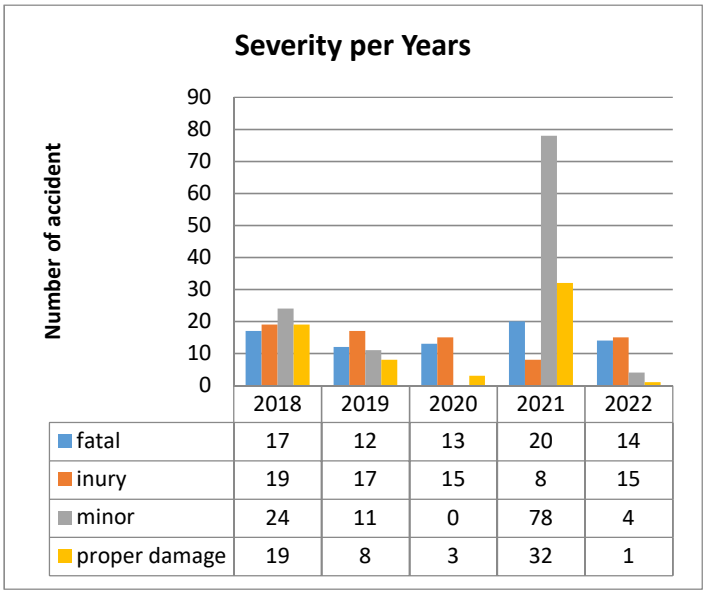


Figure 2 Accident distributions per total severity

Severity was different per year, from start study years up to 2020 the accident was decrease, unfortunately the accident was randomly increased more triple value from predecessor year.



	2018	2019	2020	2021	2022
fatal	17	12	13	20	14
inury	19	17	15	8	15
minor	24	11	0	78	4
proper damage	19	8	3	32	1

Figure 3 Accidents per severities

According to data the severity of accidents had decreased from 2018 – 2021. Unfortunately in 2022 the severity per money rapidly rose. This was caused by a variety of factors, including the expense of vehicle spare parts and other properties.

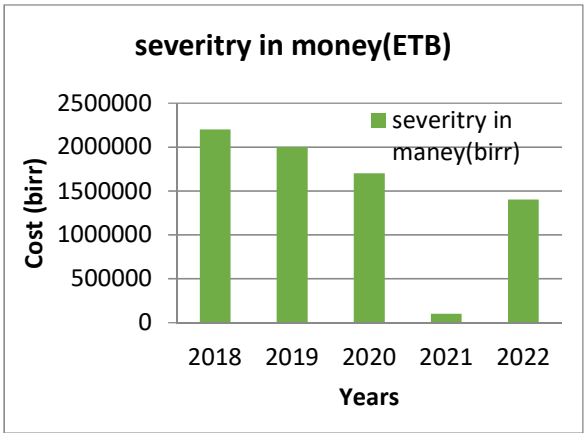


Figure 4 Severity per money

4.2 The structure of Road Safety Index

Buidling a road saety index utilized fundamental safety indicators (Figure 5).

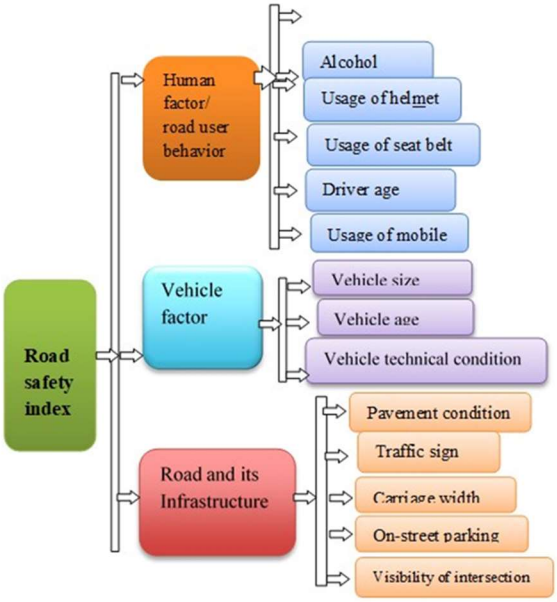


Figure 5. The structure of road performance index

4.3 Weighting and aggregating

Analytic Hierarchy Process

First Step: Develop a hierarchy structure with goal at the top level, the attribute second level and the metrics.

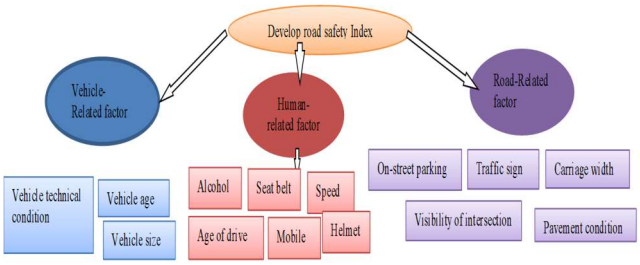


Figure 6 Constructed hierarchy structure

Second Step: Determine the relative importance of different attributes with respect to the goal by developing a pairwise matrix.

Table 4. Pairwise matrix

RSI	S	Ag	A	Sb	H	M	Vth	Va	Vs	Pc	Sp	Vi	Ts	Cw
S	1	3	5	7	5	3	7	5	9	5	7	5	3	3
Ag	1/3	1	5	7	5	3	7	5	7	5	7	5	5	3
A	1/5	1/5	1	7	5	5	7	5	7	5	5	5	5	5
Sb	1/7	1/5	1/5	1	7	5	7	5	7	5	7	3	7	5
H	1/5	1/5	1/5	-	1	5	7	5	7	5	7	5	1	5
M	1/3	1/7	1/5	1/5	1/5	1	5	7	5	5	5	5	5	3
Vth	1/7	1/5	1/7	1/7	1/5	1/5	1	5	5	5	5	5	5	5
Va	1/5	1/5	1/5	1/7	1/5	1/5	1/5	1	5	5	5	5	5	5
Vs	1/9	1/7	1/5	1/7	1/5	1/5	1/5	1/5	1	5	5	5	5	5
Pc	1/5	1/5	1/5	1/7	1/5	1/5	1/5	1/5	1/5	1	5	5	5	7
Sp	1/5	1/5	1/5	1/7	1/5	1/5	1/5	1/5	1/5	1/3	1	5	1	4
Vi	1/5	1/5	1/5	1/3	1/5	1/5	1/5	1/5	1/5	1/5	1/3	1	3	4
Ts	1/3	1/3	1/5	1/7	1/5	1/5	1/5	1/5	1/5	1/5	1	1/3	1	4
Cw	1/3	1/3	1/3	1/5	1/5	1/5	1/3	1/5	1/5	1/7	1/4	1/4	¼	1

Each element in the matrix represents a comparison between two alternatives. The diagonal elements are “1” because each criterion is compared to itself. Based on the provide details, fill in the matrix using intensity of importance give numerical value.

For example, the first row under “S” contains value like 1, 3, 5, etc, which represent the importance of “S” compared to other criteria. Similarly, fill out the rest of the matrix using the values provided for each criterion.

i. Normalizing pairwise matrix:

Table 5 Normalizing pairwise matrix

ar	S	Ag	A	Sb	H	M	Vth	Va	Vs	Pc	Sp	Vi	Ts	Cw
S	1/3.9	3/3.6.54	5	7/23.5	5/24.8	3/23.73	7/42.4	5/39.2	9/54	5/46.93	7/60.33	5/54.58	3/54.2	3/59
Ag	0.33/3.9	1/6.54	0.2/13.4	7/23.5	5/24.8	3/23.73	7/42.4	5/39.2	7/54	5/46.93	7/60.33	5/54.58	5/54.25	3/59
A	0.2/3.9	0.2/6.5	1	7/23.5	5/24.8	5/23.73	7/42.4	5/39.2	7/54	5/46.93	5/60.33	5/54.58	5/54.25	5/59
Sb	0.14/3.9	0.2/6.5	0.2/13.4	1/23.5	7/24.8	5/23.73	7/42.4	5/39.2	7/54	5/46.93	7/60.33	5/54.58	7/54.25	5/59
H	0.2/3.9	0.2/6.5	0.2/13.4	-	1/28.4	5/23.73	7/42.4	5/39.2	7/54	5/46.93	7/60.33	5/54.58	1/54.25	5/59
M	0.33/3.9	0.14/6.54	0.2/13.4	0.2/23.5	0.2/24.8	1/23.73	5/42.4	7/39.2	5/54	5/46.93	5/60.33	5/54.58	5/54.25	3/59
Vth	0.14/3.9	0.2/6.5	0.14/13.4	0.14/23.5	0.2/24.8	0.2/23.73	1/42.4	5/39.2	5/54	5/46.93	5/60.33	5/54.58	5/54.25	5/59
Va	0.2/3.9	0.2/6.5	0.2/13.4	0.14/23.5	0.2/24.8	0.2/23.73	0.2/42.4	1/39.2	5/54	5/46.93	5/60.33	5/54.58	5/54.25	5/59
Vs	0.11/3.9	0.14/6.54	0.2/13.4	0.14/23.5	0.2/24.8	0.2/23.73	0.2/42.4	0.2/39.2	1/54	5/46.93	5/60.33	5/54.58	5/54.25	5/59
Pc	0.2/3.9	0.2/6.5	0.2/13.4	0.14/23.5	0.2/24.8	0.2/23.73	0.2/42.4	0.2/39.2	0.2/54	1/46.93	5/60.33	5/54.58	5/54.25	7/59
Sp	0.2/3.9	0.2/6.5	0.2/13.4	0.14/23.5	0.2/24.8	0.2/23.73	0.2/42.4	0.2/39.2	0.2/54	0.33/46.93	1/60.33	5/54.58	1/54.25	4/59
Vi	0.2/3.9	0.2/6.5	0.2/13.4	0.33/23.5	0.2/24.8	0.2/23.73	0.2/42.4	0.2/39.2	0.2/54	0.2/46.93	0.33/60.33	1/54.58	3/54.25	4/59
Ts	0.33/3.9	0.33/6.54	0.2/13.4	0.14/23.5	0.2/24.8	0.2/23.73	0.2/42.4	0.2/39.2	0.2/54	0.2/46.93	1/60.33	0.33/54.58	1/54.25	4/59
Cw	0.33/3.9	0.33/6.54	0.33/13.4	0.2/23.5	0.2/24.8	0.2/23.73	0.33/42.4	0.2/39.2	0.2/54	0.14/46.93	0.25/60.33	0.25/54.58	0.25/54.25	1/59
Sum	3.9	6.54	13.4	23.5	24.8	23.73	42.4	39.2	54	46.93	60.33	54.58	54.25	59

Normalizing a pairwise matrix involves dividing each values in the corresponding column. This process ensures that each column of the matrix has the same sum, which can be useful for certain types of analysis or comparisons. Normalizing pairwise matrix divide each matrix value to each of the sum matrix column.

ii. Weights creating : Take the average of normalizing matrix row as a created weight

Table 6 Creating weights (Crwt)

RSI	S	Ag	A	Sb	H	M	Vth	Va	Vs	Pc	Sp	Vi	Ts	CW	Cwt
S	0.256	0.459	0.381	0.297	0.202	0.126	0.165	0.128	0.167	0.107	0.116	0.091	0.054	0.051	0.1856
Ag	0.0844	0.1529	0.3805	0.2969	0.2016	0.1264	0.1651	0.1276	0.1296	0.1065	0.1160	0.0916	0.0905	0.0508	0.1515
A	0.0512	0.0306	0.0761	0.2969	0.2016	0.2107	0.1651	0.1275	0.1296	0.1065	0.0829	0.0916	0.0905	0.0847	0.1247
Sb	0.0358	0.0306	0.0152	0.0424	0.2823	0.2107	0.1651	0.1275	0.1296	0.1065	0.1160	0.055	0.1267	0.0847	0.1092
H	0.0515	0.0303	0.0152	0.0059	0.0403	0.2107	0.1651	0.1276	0.1296	0.1065	0.1160	0.0916	0.0905	0.0847	0.0904
M	0.0844	0.0505	0.0152	0.0085	0.0081	0.0421	0.1179	0.1786	0.0926	0.1065	0.0829	0.0916	0.0905	0.0508	0.0729
Vth	0.0358	0.0214	0.0107	0.0059	0.0081	0.0084	0.0236	0.1275	0.0926	0.1065	0.0829	0.0916	0.0905	0.0847	0.0564
Va	0.0511	0.0306	0.0152	0.0059	0.0081	0.0084	0.0047	0.0255	0.0925	0.1065	0.0828	0.0916	0.0904	0.0847	0.0499
Vs	0.0281	0.0214	0.0152	0.0059	0.0081	0.0084	0.0047	0.0051	0.0185	0.1065	0.0829	0.0916	0.0905	0.0847	0.0408
Pc	0.0511	0.0306	0.0815	0.0059	0.0081	0.0084	0.0047	0.0051	0.0037	0.0213	0.0829	0.0916	0.0905	0.1186	0.0384
Sp	0.0511	0.0306	0.0152	0.0059	0.0081	0.0084	0.0047	0.0051	0.0037	0.0070	0.0166	0.0916	0.0181	0.0677	0.0239
Vi	0.0511	0.0306	0.0152	0.0085	0.0081	0.0084	0.0047	0.0051	0.0037	0.0043	0.0033	0.0183	0.0543	0.0678	0.0202
Ts	0.0844	0.0306	0.0152	0.0059	0.0081	0.0084	0.0047	0.0051	0.0037	0.0043	0.0166	0.0060	0.0181	0.0678	0.0199
Cw	0.0844	0.0505	0.0152	0.0085	0.0081	0.0139	0.0047	0.0051	0.0037	0.0043	0.0023	0.0046	0.0045	0.0169	0.0162

Calculating the average of the normalized rows. The average calculated each row is serve as the weight for that articular row. These weight reflect the relative significance or contribution of each variable represented by the rows after normalization. For example, the average for row is 0.1515. This means that the variables in this row have an average contribution of 0.1515 after normalizing. The weight s are the average of the normalized row of the matrix/

iii. Check the consistency of credited weight: multiply each un normalized pairwise matrix with created weight value then take the sum of multiplied row (Swt)

Table 7. Check consistency of the creating weight

Cwt	0.19	0.15	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.04	0.02	0.02	0.02	0.02	
RSI	S	Ag	A	Sb	H	M	Vth	Va	Vs	Pc	Sp	Vi	Ts	CW	Swt
S	0.19	0.45	0.62	0.76	0.45	0.22	0.22	0.25	0.37	0.2	0.17	0.10	0.06	0.05	4.10
Ag	0.06	0.15	0.62	0.76	0.45	0.22	0.22	0.25	0.29	0.19	0.17	0.10	0.1	0.05	3.64
A	0.04	0.03	0.13	0.76	0.45	0.36	0.36	0.24	0.28	0.19	0.11	0.10	0.09	0.08	3.27
Sb	0.03	0.03	0.03	0.11	0.63	0.36	0.36	0.25	0.29	0.19	0.02	0.06	0.14	0.08	2.58
H	0.04	0.03	0.03	0.02	0.09	0.36	0.36	0.25	0.29	0.19	0.17	0.10	0.1	0.08	2.10
M	0.06	0.05	0.03	0.02	0.02	0.07	0.07	0.35	0.20	0.19	0.12	0.10	0.1	0.05	1.44
Vth	0.03	0.02	0.02	0.03	0.02	0.02	0.01	0.25	0.20	0.19	0.12	0.10	0.1	0.08	1.17
Va	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.05	0.20	0.19	0.12	0.10	0.1	0.08	1.00
Vs	0.02	0.02	0.05	0.02	0.02	0.01	0.01	0.01	0.04	0.19	0.12	0.10	0.1	0.08	0.77
Pc	0.04	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.12	0.10	0.1	0.11	0.65
Sp	0.04	0.03	0.03	0.02	0.02	0.04	0.02	0.01	0.01	0.01	0.02	0.10	0.02	0.07	0.4
Vi	.037	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.06	0.07	0.34
Tra	0.06	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.07	0.31
Cw	0.06	0.05	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.28
ʎ	18.1	19.0	17.6	17.2	15.7	16.8	14.1	13.9	12.8	11.6	11.6	11.9	12.3		
Lambda max(average of lambda)										15.98					

To check the consistence of the credited weight, multiply each normalized pairwise matrix with the created weight value. Then, take the sum of the multiplied rows (swt). The sum of the multiplied rows is consistent across all rows.

Consistency index (CI) = $(\lambda_{max} - n)/ (n-1)$, λ = Swt/ Cwt, CI= (15.2982-14)/13= 0.1525, Random index (RI) from standard value =1.57(from table 3) Consistency ratio = CI/RI = 0.1525/1.57= 0.09712, CR value less than 0.1, then the .weights are accepted.

Table 8 Created weights

Road safety indicators	Criteria weights	Criteria weights	Weights
Speed(S)	0.18561	Human/ Driver related factors (DF)	0.734186
Age of Driver(Ag)	0.1851464		
Alcohol(A)	0.124682		
Seatbelt(Sb)	0.109158		
Helmet(H)	0.0903996		
Mobile(M)	0.072872		
Vehicle Technical Condition Vth)	0.056449	Vehicle-related factors (VF)	0.1471818
Vehicle Age(Vag)	0.04989		
Vehicle Size(Vs)	0.040842		
Pavement Condition(Pc)	0.038416	Road related factors (RF)	0.118637
On-Street Parking(Sp)	0.023858		
Visibility of8 Intersection (Vi)	0.0202466		
Traffic Sign(Ts)	0.019924		
Carriage Width(Cw)	0.016192		

4.4 Calculation and Explanations of the Result

Table 9 Human-related collected data

Indicator	Sample size	Score value			
			In %		In%
Age	382	>20 years 339	89	<20 years 43	11
Speed	382	297 in speed limit	75	>speed limit 95	25
Seatbelt	37	35 use seat belt	94	2 not use	6
Alcohol	382	99 use often and 183 use sometimes	26 and 48	191 not use	50
Mobile	382	60 use often and 115 sometimes	15.8 and 29.3 = 35	Not use 248	65
Helmet	261	21 use helmet	8	240 not use	92

Table 10 Road-related factors score values for the road (kela to Secha 4.5km)

Integrates	Score values			
				%
Pavement (surface) condition	Road 1	4	(the size >70cm)	90
	Road 2	6		
	Road 3	2		
	Road 4	-		
On-street parking	Road 1	Present	For all roads is allowed	100
	Road 2	Present		
	Road 3	Present		
	Road 4	Present		
Traffic sign	Road 1	2informatory & warring	adequate	10
	Road 2	1(warring)		
	Road 3	1(informatory)		
	Road 4	-		
Intersection visibility	Road 1	48 intersection	4 are visible	35
	Road 2	35 intersections	5 are visible	
	Road 3	16 intersections	2 are visible	
	Road 4	Intersections	all visible	
Carriage width	Road 1	4 lane with media	All	95
	Road 2	4 lane with median	80%	
	Road 3	4 lane with media	All	
	Road 4	4 lane with media	All	

Table 11 Vehicle-related factors

Indicators	Sample size	Score value			
			%		%
Vehicle age	382	72 vehicle more than 10 years	18.8	310 le \dess than 10 years	81.2
Vehicle size	382	44 vehicles larger	11.6	338 are medium and small	88.4
Vehicle technical condition	382	343 technically approved	90	39 have no approved	10

RSI = $\sum_{i=1}^{n} \frac{Ii*wi}{wt}$ where n= indicators numbers

RSI = $\sum_{i=1}^{n} \frac{Ii*wi}{wt}$

$RSI = S * 0.18561 + Ag * 0.151464 + A * 0.124682 + Sb * 0.109158 + 2H * 0.0903996 + 8M * 0.072872 + Vth * 0.0564498 + Vag * 0.04989 + Vs * 0.040842 + Pc * 0.038416 + Sp * 0.023858 + 2\,Vi0.02022466 + Ts * 0.019924 + Cw * 0.016192$

RSI = $0.7796506/1.000001 = 0.703871$

RSI= 0.7796498 == <u>RSI = 0.78</u>

RSI value shows **very good level of service.**

The value shows the city roads have a very good level of service. Most present measurements that are used to address the scale of road safety problems in a country/ city are mainly based on death rates (deaths per vehicle or per person). These rates are often too complex to be understood by ordinary people and/ administrative bodies and, in some cases, measurements are not uniform. For example numbers of road deaths per 10,000 vehicles or the number of deaths per 100,000, but RSI shows a clear understandable simple number between "0 to 1".

5. Conculsions

To show the status of the road safety problems easily, simply and in an understandable manner road safety index (RSI) is required. The objectives have been achieved; for instance identifying the possible indicators pertaining to road user risk factors such as speed, alcohol, age of driver, seat belt, helmet and mobile users, for vehicle safety factors used vehicle technical condition, vehicle age and size and in the infrastructure used pavement condition, traffic sign, on-street parking, visibility of intersection and carriage width.

Road safety indicators authorities can implement targeted intervention to address these risks. This can involves public

awareness campaigns, enforcement for speed limit and restrictions on alcohol consumption while driving. Vehicle safety indicators: by monitoring the technical condition of vehicle. This can involve regular vehicle inspection , enforcement of safety standards and promotion of safety standards and promotion of safe driving practices. Infrastructure quality indicators: by assessing the condition of pavement and other infrastructure, authorities can identify areas that require improvement and implement targeted interventions. This can involve regular maintenance, repair, and investment in infrastructure.

So, measure and combine indicators**,** create value score and relative weightings for each indicator and finally, show accurately represent the state of the road at present. And the initial research questions have been addressed. This work practically collecting relative data and analyzing using Analytic hieratic process (AHP) method are the major activities.

The final approach and aggregation methodology for RSI construction were left open-ended. More research and practical applications are required for this. The evaluation of this study, however, recommends choosing weights using the "subjective weights" approach.

The Analytic hieratic process (AHP) methodology for RSI building was used in this thesis. While there are various weighting and aggregate methods, each methodology have pros and cons of its own. This will require additional research and practical applications. Nonetheless, assigning varying weights to distinct RSI indicators in an arbitrary manner, grounded in the RSI philosophy and prior experience, can be a viable approach for RSI construction, and this approach has numerous advantages.

In conclusion, it is hoped that this road safety measurement can impact the public; it makes it easier to recognize the scope of the issue and raise awareness. It can also assist researchers in comprehending connections between various elements and a city's overall level of road safety as well as the reasons behind the desire to learn more about thw particular measurement and its indicators.

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