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Developing a safer road user behaviour index

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ABSTRACT

Road user behaviour is an essential factor of increasing the rate of traffic accidents worldwide. Road safety experts and scientists consider aspects of road users' behaviour to be the main risk factors for road fatalities. These factors include drinking alcohol, speeding, not wearing seat belts, not wearing helmets when riding two-wheeled vehicles, not using child restraints, consuming illegal drugs, and being distracted by mobile phone use. This paper aims to investigate the role of these factors in assessing the road user behaviour through aggregating them and build a composite indicator that can be used in countries benchmarking and cross countries comparison, then identifying most successful practises. To achieve this aim, data related to the selected indicators, life-saving rate, and real crash data were collected. The indicators were weighted using simple and theoretical methods. The weighted indicators were aggregated using simple additive method. The developed index was applied to 12 European countries to test the validation of the index through investigation the correlation between index' ranking of countries with the ranking according to the rate of fatalities. It is concluded that the developed composite indicator can be used to assess the role of using the protection system and speeding in the severity of the road crashes. However, the role of the remaining factors in the likelihood of crashes occurrence needs more investigation. It can be concluded also that the road users' behaviour is not the only factor of reducing the road fatalities in some countries. This enhances the multidimensional system approach of defining the road safety. Based on this, it is recommended to consider other factors in conducting research, developing indices of road safety, and in recommending solutions. The results show also that the UK, Sweden, Ireland and Ireland have the most successful strategies to improve the road user behaviour among the selected countries; therefore, it is recommended to take lessons from these practices.

1. Introduction

Road safety is a significant issue worldwide. The rate of road crashes has been increasing and the consequences are becoming more severe. The World Health Organization (WHO) [1] reported that about 1.25 million people have been killed and about 20 to 50 million people injured on roads due to traffic incidents. Therefore, actions have been taken by global organisations to improve road safety. Saving one million lives is the target of the Decade of Action for Road Safety (2011−2020), which was officially proclaimed by the United Nations (UN) General Assembly in 2010 [2,3]. The UN's 2030 Agenda for Sustainable Development Goals (SDG) [4] organizes that road safety is an essential requirement for ensuring healthy lives. Therefore, reducing the rate of road fatalities by half by 2020 is included as a target in two of the goal groups of the SDG. Five pillars are recommended to be considered in plans for improving road safety: managing the road safety system; developing safer road infrastructure; developing safer vehicle design; improving post-crash response and enhancing safer behaviour by road users [1,2].

Road user behaviour is the main contributing factor in the majority of road crashes. The recent vision on road safety presented by Sweden in their *Vision Zero* and the Netherland in their *Sustainable Safety* principles consider the road user in two ways. The first point is that the road user is the weakest element of the transport system, so road infrastructures and vehicles should be designed to accommodate the limitations of road users' bodies. This is reflected by unintentional mistakes on roads and by people's inability to control a crash event. The second point, considered in this paper, concerns intentional mistakes resulting from road users' misbehaviour. Road users should have an attitude of being prepared to improve their behaviour to avoid common intentional mistakes such as speeding and not wearing seat belts [5–9].

Road safety experts consider aspects of road users' behaviour to be the main risk factors for road fatalities. These factors include drinking

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alcohol, speeding, not wearing seat belts, not wearing helmets when riding two-wheeled vehicles, not using child restraints, consuming illegal drugs, and being distracted by mobile phone use [1,10]. These seven factors will be explored briefly in this paper. It will be demonstrated that reducing the risk impact of these factors plays a significant role in improving road safety. It will also be demonstrated that legislation of road safety with effective enforcement is the best way to encourage safer behaviour by road users. It is recommended by road user experts and scientists to strengthen laws regarding road use by considering these seven factors and developing manners for more effective enforcement [1,11].

2. Research motivation

It is observed that many countries lack effective road safety legislation and enforcement. In low-middle income countries, for example, the common behaviour of drivers and riders is not wearing seat belt. In addition, it is rarely to use protective facilities by motorcyclists and cyclists. Furthermore, drivers are not familiar with the child restraints system [11].

On the other hand, there is a noticeable lack in the studies that conducting the indicators and assessment techniques of the road user behaviour; especially in the low and middle-income countries. The main reason behind that is the lack of adequate database and collection system of information relating to drivers and passengers behaviour. Some interested organisations, such as the WHO, have efforts to establish road safety dataset including data related to the seven risk factors of road user behaviour. The WHO also published assessment reports based on the accessed dataset [1,2]. However, these reports consider each factor individually in assessing the road safety situation. This may not interpret the meaningful idea of a complex multidimensional system and produce troubles from different tends resulting from many indicators [12–14]. In addition, the aggregated index is more preferable by policy makers to set targets and priorities, to benchmark and compare strategies, and to discover the most effective strategy [12]. These are most likely support the assessment of effectiveness of a national road safety legislation and enforcement system.

Therefore, there is a need to find a composite indicator has the ability to measure to what degree a country's traffic accidents result from road user behaviour, to assess the effectiveness of a national road safety legislation and enforcement system, to improve the road user behaviour and to prevent the intentional mistakes such as speeding.

3. The aim and objective of the research

The main aim of this research is developing an aggregated safer road user behaviour index (SRUBH) to consider the main risk factors related to the intentional mistakes that could not be accommodated by the road infrastructure or vehicle design. The main objectives are:

a. To identify the potential indicators that related to the risk factors of the road user behaviour and select the indicators of SRUBH
b. To identify the variables that could be used to measure the selected indicators.
c. To outline a methodology of aggregating indicators
d. To apply the developed index and achieve its purposes

4. Risk factors of road user behaviour

This section presents a review of literatures considered the risk factors of the road user behaviour and a brief explanation of these factors. The importance, impact and the life-saving percentage shown by improving each factor are the points considered in explaining each factor.

Table 1 shows a summary of the reviewed literature in terms of the selected indicators and the variables used to measure them. Some of these studies used road user behaviour indicators to aggregate them with other indicators reflecting other dimensions of road safety performance, such as road and vehicles and construction composite indicators. It can be noticed that the two most commonly used indicators are drunk drivers and wearing seat belts, the latter as an indicator of using the protection systems provided in vehicles. On the other hand, mobile phone use is not used as an indicator by the reviewed research, as this factor has only been considered more recently [1]. Consuming drugs has also not been widely selected as an indicator, as it is considered only by the SafetyNet project [18–20].

4.1. Speeding

Setting speed limits is essential to limit the impact energy between vehicles and people in a crash event to a level that could reduce the severe consequences of road crashes [7,36]. Recently, and according to the new vision of road safety systems, speed limits have been reduced, which has resulted in a 30% reduction in road accident fatalities. It has been demonstrated that a speed reduction of one km/h leads to a 5%t reduction in the number of fatal accidents [21]. Increasing adherence to driving within the set limit is essential for maximising the benefits of setting a speed limit.

Exceeding the speed limit is considered a crime in the legislation of road safety and providing an effective enforcement system is highly recommended by the WHO [11]. Speed cameras are enforcement instruments that have helped to address speeding problems in the UK, reducing the frequency of people driving at excessive speeds by about 70% and the rate of road fatalities by roughly 30% per annum between 1990 and 2010 [11]. Other effective enforcement instruments are also recommended, such as mobile radar controls, electronic vehicle identification (EVI), intelligent speed adaptation, speed exceedance alerts in vehicles, and speed bumps on roads [17,37–39].

4.2. Drunk drivers

Drinking alcohol is one of the most common contributory factors to serious road accidents [17,21]. It is the main factor in 14% to 40% of fatal accidents in Europe [10,40,41]. Blood alcohol content (BAC) is used as an indicator to measure this issue [17]. Studies have demonstrated that the probability of a crash occurring is doubled with each 0.02% increase in BAC [10]. The factor of drinking alcohol is controlled through road safety laws, with a maximum BAC of 0.05 g/dl allowed for the general population, and ≤0.02 g/dl for young drivers [11,17,40]. Passing this law has led save nearly quarter of the road users' life [11].

Enforcement of laws against drinking alcohol and driving has had a role in reducing more road fatalities by around 9% (Elvik and Vaa, 2004, adapted by Hakkert et al. [19]). Breath testing is the most effective method of detecting BAC, with other methods including chemical test tubes and electronic screeners [17,21].

4.3. Consuming illegal drugs

It has been reported in the Netherlands that road crashes resulting from consuming drugs or drugs with alcohol occur at the same rate as crashes that result from drinking alcohol only [17]. Two types of drugs are considered in the research into road safety factors: legal drugs prescribed by doctors and illegal drugs in abusive doses [19]. Morphine and heroin are the most dangerous drug types, which play a role in increasing the rate of road risk by 32 times, while cannabis has the same effect as drinking alcohol to a 0.05 BAC level [19]. However, the methods for testing drug content remain challenging; therefore, no enforcement method can be identified as the most effective [40].

Table 1
Summary of the reviewed literatures in term of the variables of the indicators.

Previous research	Indicators				
	Speeding	Drunk-drivers	Using seat-belts	Using helmets	Using chid restarints
ETSC [21]	% above legal limit	% of driver above legal limit	% wearing seat belts	–	% using child restraints
Al Haji [22]	–	–	% wearing seat belts	% of using helmets	–
The European SafetyNet project [19,20]	% above legal limit	% road deaths involving drinking alcohol	% wearing seat belts in front and rear seats	% of using helmets	–
Hermans [23] and Hermans et al. [24]	% road users <speed limit	% road users < max BAC	% wearing seat belts	–	–
SUNflower study [5]		% road deaths involving drinking alcohol	% wearing seat belts in front and rear seats		
Wegman and Oppe [25]	–	–	% wearing seat belts	–	–
Gitelman et al. [26]	–	% road deaths involving drinking alcohol	% wearing seat belts	–	–
The DaCoTA study on Road Safety Index [27]	–	• Road-side police alcohol tests per 1000 population • % of driver above legal limit	% wearing seat belts in front and rear seats	–	–
Shen [28] and Shen et al. [29]	% above legal limit	% of driver above legal limit	% wearing seat belts	% using helmets	% using child restraints
Oluwole et al. [30]	% above legal limit	% of driver above legal limit	% wearing seat belts	% using helmets	% using child restraints
Gitelman et al. [18]	% above legal limit	% road deaths involving drinking alcohol	% wearing seat belts in front and rear seats	% of using helmets	–
WHO [1]	–	% of road deaths involving alcohol	% wearing seat belts in front and rear seats	% of drivers and riders using helmets	% children using child restraints
Chen et al. [31]	–	% fatalities involving alcohol	% of seat belt use front seat	% of using helmets	–
Tesic et al. [32]	% above legal limit	Car drivers < max BAC	Seat belt wearing rate at front seats	–	–
Jameel and Evdorides [33]	• The regulating of national speed limit • Enforcement rate	• The regulation of national drunk-driver law with the allowable BAC limits • The applying of breath test • Enforcement rate	• The regulation of national motorcycle helmet law with helmet standards for passengers and drivers • Fastening of helmets • Enforcement rate	• The regulation of national wearing seat-belt law • The application of laws on front and rear seats • Enforcement rate	• The regulation of national child-restraints law with restriction on sitting in front seats • Enforcement rate
Jameel [34]	Enforcement effectiveness score of speeding	Enforcement effectiveness score of drunk-driver	Enforcement effectiveness score of wearing seat-belt	Enforcement effectiveness score of wearing helmet	Enforcement effectiveness score of using child-restraints.
Jameel and Evdorides [35]	Enforcement effectiveness score of speeding	Enforcement effectiveness score of drunk-driver	Enforcement effectiveness score of wearing seat-belt	Enforcement effectiveness score of wearing helmet	Enforcement effectiveness score of using child-restraints.

4.4. Using a seat belt

Road fatality rates are reduced by around 50% when road safety laws are strengthened regarding wearing seat belts with firm police enforcement [11,21]. Studies show that front-seat passengers wearing seat belts has a more positive impact by roughly 25% than rear-seat passengers wearing seat belts [42]. Enforcement is established to record offences and supplemental vehicle technologies, such as seat belt reminders and seat belt ignition interlock, help to increase seat belt use by vehicle occupants [37].

4.5. Child restraints

Developing child restraint laws for both rear and front seats results in reducing fatal injuries among children by a significant percentage [27,43]. It is reported that roughly 70% of infants' lives and 54% of the lives of children below the age of five can be saved when child restraints are applied. It has also been reported that serious injuries among children are reduced by 90% by this intervention [10,11,21].

4.6. Two-wheel transport helmets

The use of helmets by drivers and riders of two-wheeled vehicles plays a significant role in reducing fatal and serious injuries. It is reported that 20% to 45% of motorcyclist fatalities and around 70% of severe injuries can be prevented by using helmets [10,19,22].

4.7. Using mobile phones while driving

Using mobile phones while driving results in distraction [1,44,45]. This leads to drivers needing a longer response time to take action in case of sudden events and a longer distance to reduce their speed [45,46]. Recent research has demonstrated that this leads to increases in road fatality rates of 6.6% to 100% [45]. It has also been shown that hand-held phones affect physical performance in addition to cognitive performance. Therefore, prohibition of using hand-held mobile phones while driving is included in road safety laws with enforcement penalties (Brace et al. 2007 adapted from Rahman et al. [45]).

5. Methodology

To achieve the main aim of this paper, seven steps are followed, as outlined below.

5.1 Collecting data
5.2 Selecting variables of indicators based on the availability of reliable and consistent data.
5.3 Weighting variables using simple and theoretical methods.

5.4 Aggregating variables.
5.5 Applying the developed index to a select set of countries through ranking countries according to the developed indices.
5.6 Testing the validation of the developed models and select the final model.
5.7 Investigating the use of the developed composite indicator in rating countries

These steps will be explained in more detail in the following sections.

5.1. Collecting data

Reliable data from reliable sources are needed to ensure quality and accuracy of the variables. A lack of the required data may restrict the developer's ability to build effective composite indicators [16]. In this research, three sets of data are needed for different purposes.

- Group 1, variables data to measure the indicators,
- Group 2, life-saving rate, which is needed for weighting indicators
- Group 3, data related to real cash details to test that validation of the developed composite indicator and select the most proper index.

Group1. The first group of data is the data needed to measure the indicators and decide on the final list of variables. The WHO [1] and the European Transport Safety Council (ETSC) [47] provide reliable data, relevant to the indicators of road user behaviour, and consistent data in terms of uniform definitions of measurement. These data are shown in Table 2. The data in this group are categorised into:

a. Drunk-driving data, which represents the rate of traffic deaths involving drinking alcohol [1].
b. Child restraints data, which reflects percentage of children using child restraint [1].
c. Data regarding wearing helmets, which represents the percentage of drivers and passengers on two-wheeled vehicles wearing helmets [1].
d. Seat belt data, showing the rates of front seat occupants (including drivers) wearing seat belts and of rear seat occupants wearing seat belts [1].
e. Speeding data in terms driving over speed limit [47].
f. Drug-driver data in terms of percentage of self-declared drivers that they are in influence of drugs [47].
g. The percentage of drivers using mobile phones [47].

The first four categories of data are collected for 124 countries, which represent about 69% of the total WHO members as these countries have recorded and accessed data regarding these categories. However, it has been challenged to find data related to the last three categories which are speeding, drug-drivers and distracting by using mobile phone for all the selected countries. The ETSC has accessed data of some of the European countries only, which are 12 counties as shown in Table 2. Therefore, the developed aggregation model will be applied to these countries only. Table 2 shows the collected data for the selected countries.

Group 2. The second set of data is needed to weight the indicators. The percentage reduction in road fatalities caused by improving each factor is used to weight the indicator reflecting the relevant factor. The collected data for this weighting are shown in the second column of Table 3.

Group 3. The third set of data represents the rate of road fatalities per 100,000 population per each country, which is needed for comparison with the results of applying the index developed in this study. These data, which are shown in Table 2, are collected from the WHO website [1].

5.2. Selecting variables

Variables should be selected not only on the basis of their relevance to the phenomena of the indicators but also based on the availability of reliable data. As some of selected indicators are related to risk factor of the likelihood of accident and others related to the severity of the occurred accidents, the selected indicators are grouped into likelihood and severity indicators. The used variables for measuring the indicators are shown as follows.

- The crash likelihood indicator resulted from road user mistakes. These are
  a. Drunk drivers – measured by the rate of traffic deaths involving drinking alcohol.
  b. Speeding- measured by the percentage of speed limit offences
  c. Drug-drivers- measure by the percentages of self-declared behaviour who are under the influence of drugs
  d. Distraction by using mobile phone during driving- measured by the percentages of offences.

- The variables of the crash severity indicators resulted from road user mistakes. These are
  a. Child restraints – measured by the percentage of children using child restraints.
  b. Wearing helmets-measured by the percentage of two-wheels riders wearing helmets.
  c. Wearing seat-belt. Measured by the percentage of front and rear seat occupants of cars wearing seat belts.
  d. Speeding - measured by the percentage of speed limit offences

Table 2
Variables of indicators data collected from WHO report [1] and ETSC [47].

Countries	Rate of traffic deaths involving drinking alcohol	% of children using child restraints	% helmet wearing rate	% seat-belt wearing rate (front seats including drivers)	% seat-belt wearing rate (rear seat)	% driving over speed limit	% drivers under the influence of drugs	mobile phone offences per 1000 population	Rate pf Fatalities per 100,000 population
Austria	0.07	0.45	0.95	0.86	0.65	0.44	0	0.20	5.2
Belgium	0.25	0.52	0.99	0.85	0.85	0.43	0.03	0.04	5.8
The Czech Republic	0.1	0	0	0.98	0.72	0.25	0	0.03	5.9
United Kingdom	0.16	1	1	0.95	0.88	0.37	0.13	0.04	3.1
France	0.29	1	0.96	0.99	0.87	0.46	0.16	0.05	5.5
Ireland	0.16	1	0.98	0.94	0.89	0.38	0.1	0.04	4.1
Sweden	0.19	0.96	0.97	0.98	0.84	0.35	0.09	0.04	2.8
Serbia	0.17	0.28	0.86	0.75	0.1	0.44	0	0.04	7.4
Poland	0.16	0.89	0.97	0.84	0.59	0.59	0.1	0.06	9.7
Slovenia	0.32	0	0	0.92	0.69	0.39	0.09	0.04	6.4
Israel	0.04	0.52	0.98	0.89	0.9	0.64	0	0.06	4.2
Norway	0.32	0	0.99	0.97	0.96	0.45	0	0.05	2.7

Table 3
Collected saving life rate with the aggregation process to find an aggregated rate for each indicator.

Indicators	% Saving life	Aggregated saving life (Mean)	
Speeding	30% [11,17]	30/100 = 0.3	0.3
Drunk	14–40% [10]	Mean = (40 + 14)/2 (100) = 0.27	0.265
Driver	26% [19]	26/100 = 0.26	
Drug consuming	Road fatalities involving drug only = 1/2 the fatalities by alcohol [11,18,21]	0.5 *0.265 = 0.1325	0.13
	40%–65% [11,18,21]	(40 + 65)/2(100) = 52.5	0.56
Seat belt	60 [11]	60/100 = 0.6	
	40–50% front seat [42]	(40 + 50)/2(100) = 45	0.45 front seat
	More effective than rear seats by 25% [42]	0.34	0.34 rear seat
	20% to 45% for motorcyclists [10,19,22]	(20 + 45)/2(100) = 0.325	
Helmet	70% [11,18,21]	0.7	0.37
	42% [2]	0.42	
Child restraints	Children under age 5 by about 54% [10,11,18,21]	673,649.68/7383009 = 0.091243	0.05
		0.54(0.091243) = 0.049271	
Mobile phone	6.6% to 100%. [45]	(6.6 + 100)/2(100) = 0.83	0.58
	17% to 54% [46]	(17 + 54)/2(100) = 0.355	

5.3. Weighting variables

Weighting is an important step to reflect the relative importance of each indicator and its impact on the overall level of road safety [15,16]. This step is used in the case of constructing a composite indicator. Different weighting methods have been used in previous studies to assign weights to the selected indicators, some uses equal weighs and other unequal weights.

Simple weighting assumes that all indicators have equal importance and an equal effect on the overall situation [22–24]. It is used in constructing the valid indices, such as the human development index and the sustainability index.

It can be claimed, however, that this method is used only when there is insufficient knowledge about the indicators [16]. Therefore, sources of knowledge are needed to estimate accurate weighting of variables. These sources include theoretical [22,27–29] and expert opinions [17,22,25,26]. Expert opinion is not considered in this study because of difficulties in finding sufficient number of responses.

Statistical methods have been also used based on considering the statistical characteristics of data, such as variance between variables, in weighting those variables [25,26]. However, some significant theoretical and practical data may be excluded or assigned less weight due to problematic data characteristics [16]. Therefore, this method is not considered.

In this study, two methods of weighting are used, the simple method and the theoretical method.

Regarding the theoretical method, the effect of implementing policies regarding the improvement of road user behaviour in terms of lives saved by implementing interventions is the measure used in weighting the variables of road user behaviour indicators. Different sources have been used for collecting data. Therefore, some indicators have different values for life-saving rates. To find one value for each indicator, the percentages are aggregated using the AVERAGE function, as shown in the third column in Table 3.

Regarding the aggregated life-saving rate of using child restraints, the available data are for children under the age of five. Therefore, there is a need to find the equivalent of this value in terms of the general population. For this, the population size of children under five years has been collected from the WHO official website for the calculation below.

$$\text{Rate of children under five years} = \frac{\text{population of children under five}}{\text{general population}} = 0.091243 \tag{1}$$

This rate is used to find the adjusted rate of lives saved by using child restraints as shown in Table 3. The aggregated rate of life-saving is standardised using a distance to maximum formula to find the final weight of each variable. Three steps are followed in the weights standardisation [34]:

a. Scaling the maximum saving life rate which is the saving life by implemented the seat belt intervention by one.
b. Finding the other life-saving rates according to the new scale using Eq. (1):

$$\text{Indicator i Scale} = \frac{\text{the aggregated saving life of indicator i}}{\textit{maximum saving life rate}} \tag{2}$$

c. Finding the final weight of each indicators using Eq. (3).

$$\text{Wi (weight of indicator i)} = \frac{\text{Indicator i scale}}{\text{SUM of indicators scale}} \tag{3}$$

Regarding the sub-indicators of the seat belt indicator, which are front seat occupants and rear seat occupants, the same steps ae followed, assuming that the maximum life-saving rate is that of the indicator wearing the seat belt by the rear seat occupants (0.45) as shown in Table 4. The final weight of each is then multiplied by the final weight of the overall indicator for wearing seat belts (0.22).

5.4. Aggregating variables

Simple additive is the method used in aggregating variables [16]. Eq. (4) is the formula used in calculating the summation of the individual indicators' scores resulting from ranking of these countries according to the individual indicator assuming linear aggregation.

$$SRUBHc = \sum_{q=1}^{Q} \text{Wq Iqc} = SRUBH\ Likelihood + SRUBH\ Severity \tag{4}$$

where: SRUBHc = safer road user behaviour composite indicator for country c, Wq = weight of indicator q, and Iqc = the score of country c representing its ranking according to indicator q.

Because two weighting methods are investigated in this study, Eq. (4) is developed to identify the SRUBHc of the likelihood score and the SRUBHc of the severity score. Eqs. (5a) and (6a) are used to find the SRUBHc score of the likelihood of crashes, respectively, when using unequal weighting method. Eqs. (5b) and (6b) are used to find the likelihood and severity scores when using equal weighting.

$$SRUBHc\ Likelihood = 0.115(I_{speeding}) + 0.1(I_{drunk-driver}) + 0.23\ (I_{Mobile\ phone}) - 0.06\ (I_{drug-driver}) \tag{5a}$$

Table 4
Estimated weights of the selected indicators using theoretical method.

Indicators	Aggregated saving life rate	Weight of indicators	
		Scale of indicator	Final weights of indicators
Drunk drivers	0.265	0.46	0.10
Seat belt	0.56	0.97	0.22
Front seats	0.45	1	0.12
Rear seats	0.34	0.75	0.10
Helmet	0.37	0.64	0.14
Child restraints	0.05	0.09	0.02
Speeding	0.3	0.52	0.23
Drug driver	0.13	0.22	0.06
Distraction by mobile phone	0.58	1	0.23
Sum	3.045	4.41	1

$$SRUBHc\ Likelihood = (I_{speeding}) + (I_{drunk-driver}) + (I_{Mobile\ phone}) - (I_{drug-driver}) \quad (5b)$$

$$SRUBHc\ Severity = 0.115\ (I_{speeding}) + 0.12\ (I_{front\ seat-belt}) + 0.10\ (I_{rear\ seat-belt}) + 0.14\ (I_{helmet}) + 0.02\ (I_{chid.seat}) \quad (6a)$$

$$SRUBHc\ Severity = (I_{speeding}) + (I_{drunk-driver}) + (I_{Mobile\ phone}) + (I_{drug-driver}) \quad (6b)$$

As the speeding indicator is used twice, in likelihood and severity models and to avoid the double counts, the weight of this indicator is divided by two, 0.115 for each model.

5.5. Applying the proposed developed index

The aggregating procedure [16] is applied for the selected 12 countries as follows:

a. Ranking the countries according to each indicator individually. The purpose of this step is to avoid the difference in the terms of the collected data. For example, the drunk-driver indicator measured by the rate of fatalities involved drinking alcohol while the indicator of distracting by using mobile phone is measured by the percentages of offences per 1000 population. Therefore, the ranking method [16] is used to avoid errors resulting from different units of measures. The results of this step are shown in Table 5.
b. The second step is finding the likelihood, severity and the total scores for each country using Eqs. (4), (5a), (5b), (6a), and (6b). The results are shown in Table 6.
c. The third step is ranking the countries according to each found result of likelihood, severity, and total scores as shown in Table 7.

Table 6
The found likelihood, severity and the overall scores using the two weighting methods.

Countries	Simple weighting			Theoretical method		
	Likelihood score	Severity score	Total score	Likelihood score	Severity score	Total score
Norway	30	21	51	2.695	1.935	4.63
Sweden	16	12.5	28.5	1.25	1.77	3.02
UK	12	9	21	1.315	1.385	2.7
Ireland	15	12	27	1.47	1.8	3.27
Israel	24	23.5	47.5	2.27	2.92	5.19
Austria	21	27	48	2.025	3.585	5.61
France	25	19	44	3.01	2.49	5.5
Belgium	23	20.5	43.5	1.98	2.75	4.73
The Czech Republic	11	21	32	0.285	2.295	2.58
Slovenia	24	27.5	51.5	2.225	3.335	5.56
Serbia	24	32.5	56.5	1.95	4.42	6.37
Poland	25	28.5	53.5	2.835	4.185	7.02

5.6. Validating the developed composite indicator

To test the validation of the developed models and select the most appropriate one, the correlation between the ranks of the countries according to each score shown in Table 7 and the ranking according to the rate of fatalities is tested. This correlation is measured by Spearman's rank correlation coefficient R, which is used in testing the relationship involving ordinal variables. It is used when the variables tend to change together but not necessarily at a constant rate. It varies between −1 and 1; where 1 indicates that the two variables rise and fall together with

Table 7
Countries ranking according to likelihood, severity and the overall scores.

Countries	Simple weighting			Theoretical method		
	Likelihood score	Severity score	Total score	Likelihood score	Severity score	Total score
Norway	12	7	9	10	4	5
Sweden	4	3	3	2	2	3
UK	2	1	1	3	1	2
Ireland	3	2	2	4	3	4
Israel	7	8	7	9	8	7
Austria	5	9	8	7	10	10
France	10	4	6	12	6	8
Belgium	6	5	5	6	7	6
The Czech Republic	1	6	4	1	5	1
Slovenia	8	10	10	8	9	9
Serbia	9	12	12	5	12	11
Poland	11	11	11	11	11	12

Table 5
The rank of countries according to each indicator individually.

Countries	Drunk-driver	Using child restraint	Helmet wearing	Seat-belt wearing (front seats)	Seat-belt wearing (rear seat)	Speeding	Drug-drivers	Distracting by mobile phone	Rate of fatalities per 100,000 population
Norway	11	8	2	3	1	9	6	4	1
Sweden	8	2	4	2	7	2	4	2	2
UK	4	1	1	4	4	3	2	3	3
Ireland	5	1	3	5	3	4	3	3	4
Israel	1	4	3	7	2	12	6	5	5
Austria	2	6	5	8	10	7	6	6	6
France	10	1	5	1	5	10	1	4	7
Belgium	9	5	2	9	6	6	5	3	8
Czech Republic	3	8	7	2	8	1	6	1	9
Slovenia	12	8	7	6	9	5	4	3	10
Serbia	7	7	6	11	12	8	6	3	11
Poland	6	3	4	10	11	11	3	5	12

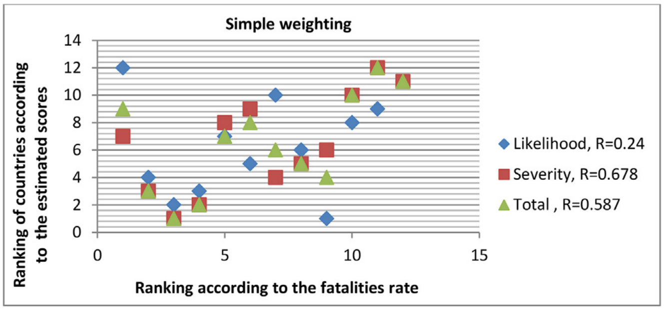

Fig. 1. The results of correlation test of the aggregated indices using simple weighting method.

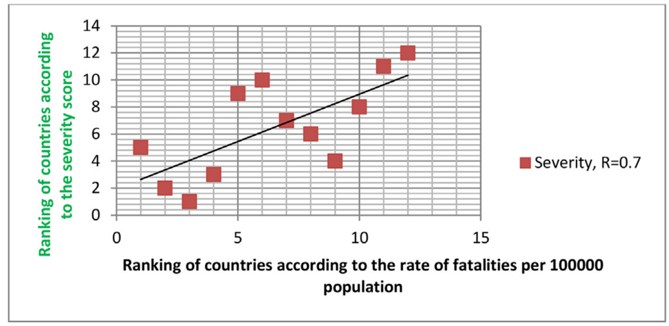

Fig. 3. The results of correlation test of the aggregated indices using unequal weighting method assuming speed weighting is 0.23.

very strong correlation, while −1 means that the two variables are very strong opposites [48–50]. The IBM SPSS statistics 24 were used to identify R. The results are shown in Figs. 1 and 2.

The results shows that the ranking of countries according to the composite index developed using unequal weighting method are more correlated with the ranking of countries according to the rate of fatalities. In addition, the severity composite indicator model produced more validated results than the overall composite indicators while the likelihood composite indicators is significantly invalid as Rs are diverted than 1.

Therefore, the developed severity composite indicators are considered valid to assess road user behaviour regarding using the protecting system; wearing seat belt, wearing helmet, using child restraints system, and speeding. While the indicators of the likelihood model need more investigation. It is important to investigate here the validation of the selected model in case of weighting speeding indicator by its original identified weights, 0.23. The results are shown in Fig. 3. It can be noticed that the correlation is less when using speeding weight of 0.23; therefore, the Eq. (6a) is used with its adjusted weights.

5.7. Rating countries according to road user behaviour

Road safety rating is a method of presenting the results in relative objective terms [51]. It has been used recently as a tool of road infrastructures assessment [52], and for vehicle assessment [53]. Rating road safety is highly recommended by the UN in their recommendations of the Decade of Actions in Road Safety; as a tool for benchmarking countries, quantifying targets and assessing the progress [51,54].

The developed composite indicators can be used in rating countries according to the road user behaviour. The following steps can be followed to rate countries according to the developed severity composite indicator of road user behaviour [34].

a. Finding the maximum and minimum potential scores of the developed composite indicator.

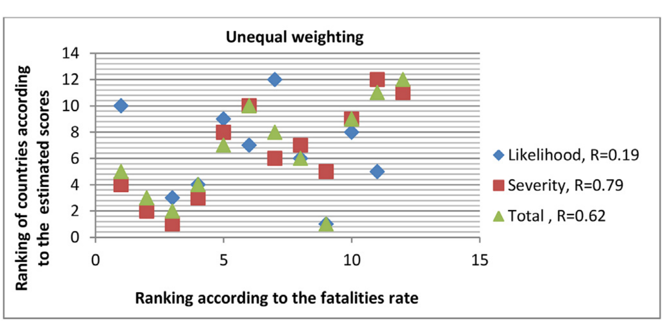

Fig. 2. The results of correlation test of the aggregated indices using unequal weighting method assuming speed weight is 0.115.

The minimum score is found when all the individual indicators have full score that the related activities are full implemented and successful. For example, when all drivers wearing seat belt, the related indicator has score of 1. While when all the drivers obey the speed limit, the speeding indicator has zero value. The countries assessed with full scores will have the top rank. Based on that, the minimum SRUBH equals to 0.495 reflecting best performance.

The maximum score is when all the activities related to the selected indicators are not implemented. In this case, the county with this performance will be at the bottom of the ranking list. Therefore, it will get the highest score. It can be computed when substituting the values of the selected indicator with lowest rank which reflect the number of countries, 179 [1]. Then, the maximum score is 88.605.

b. Finding the boundaries of the ratings. The rating range is suggested being divided into five ratings, as most common rating classes [34], as shown in Fig. 4. The maximum and minimum range boundaries of each class can be found simply using Eq. (7).

$$\text{Range of class} = \frac{(\text{Maximum score} - \text{Minimum score})}{(\text{Required number of classes})} \tag{7}$$

The results are shown in Fig. 4.

c. Validate this methodology by applying to all countries. Unfortunately, the unavailability of data regarding the speeding indicator has made this step as inapplicable. Therefore, it is recommended to focus on developing an effective system of recording data related to offensive drivers and passengers.

6. Discussion of the results

a. The lack of the necessary data related to the potential indicators of assessing the road user behaviour at national scale is the main criterion of identifying the limitation of this research. These limitations are related to:
   - The selection of indicators of the suggested composite indicators SRUBH. These indicators represent the seven risk factors of road user behaviour as reported by the global reports of road safety.
   - The variables used to measure the indicators which are mentioned in section 5.2.
   - The number of countries that are selected to apply the suggested SRUBH Index, as the data needed to measure all the selected indicators are available for 12 selected countries only.
   - The missing step of the validation test of the suggested rating methodology.

Very high performance (<18)	High performance (18-<36)	Medium performance (36-<53)	Low performance (53-<71)	Very low performance (>71)

Fig. 4. The suggested classes of the aggregated index of road users' performance on a national scale.

b. The selected indicators are classified into two groups according to their impact on the crash occurrence or severity. The likelihood indicators which are related to the factors that leads to increase the probability of crashes occurrence include speeding, drunk-drivers, drug-drivers and using mobile phones during driving. The severity indicators which are related more to the level of crashes severity level include the indicators of wearing seat belt, wearing helmet, using child restraints. Speeding is considered common indicator, as it is a main factor of both likelihood and sever crashes.
c. Two weighting methods are investigated. The first method is simple weighting method assuming equal weighting, that all factors have the same effect. The second method is unequal method assuming that each factor has different scale of effect based on the saving life rate resulting from implementing strategies related to each factors.

The results demonstrated that the second weighting method is more valid to use. The results of determining the weighs of indicators shows that speeding, wearing seat belts and using mobile phone have the highest weighs as their effects are more significant. Because speeding indicator is used twice, in likelihood and severity models, its weight is divided by 2, 0.115 as a likelihood indicator and 0.115 as a severity indicator. However, this needs more investigation. Therefore, the selected aggregation model is tested again with speeding weighting of 0.23 as shown in Fig. 3. The result shows less correlation than using weights if 0.115.

d. Correlation between the ranking of countries according to the developed SRUBH index and the ranking according to the rate of fatalities per 100,000 population is investigated to select the model of aggregation and the selected indicators. The suggested likelihood composite indicators have insignificant correlation while the severity composite indicators have stronger correlation which is even more significant that the overall composite indicators. Therefore, Eq. (6a) is selected as the aggregation model of finding the severity SRUBH index.
e. To achieve the purpose of developing the SRUBH composite indicator in benchmarking countries, rating methodology is suggested. The general steps of this methodology is adopted from Jameel [34] which is used to rate countries according to more comprehensive developed indicator.

Rating is highly recommended by the UN and other agencies interesting in road safety for:

- Assessing the road user behaviour at country level according to their obeying the road safety laws and regulations. For example, when the rate of drivers and riders wearing the protecting system is very high and close to rate at countries with very high performance class, then the severity score will be less. These countries can be grouped within very high performance class. As this rate is going to be less, the severity score will be higher and the performance level will be going to be moderate to low.
- Ranking countries according to the level of road user behaviour. This can be based on the final score and grouping according to the boundaries of the proposed rating system.
- Assessing the effectiveness of the road safety legislation and enforcement system. As the severity score s higher, it means that the effectiveness is less and needs improvement.
- Comparing between strategies adopted by each country to improve the road user behaviour. This will help in identifying the effective national strategies that succeeds in improving the road user behaviour and reduce the rate of traffic accidents resulted from road user mistakes. Then, other countries can take lessons to improve their road user behaviour.
- Quantifying and setting targets by policy makers related to the road user behaviour issues and road safety issues.

However, the suggested methodology requires validation test which was not possible because of the lack of accessed data. Therefore, it is recommended to find a method of validating the proposed methodology of rating.

f. The results of the severity score resulted from, the selected aggregation model, Eq. (6a), shows that the UK, Sweden, Ireland, and Norway have the best road user behaviour in terms of using the protecting system and driving within the speed limit. Their ranking according the rate of fatalities shows that these four countries have the least rates which fit with the results study with very slight difference in ranking. While Slovenia, Poland, and Serbia have the worst behaviour as they have higher SRUBH scores. They also have higher rate of fatalities than the other selected countries.

However, the remaining countries have different position in the ranking according to the SRUBH scores than their position in the rate of fatalities ranking. For example, Austria shows less obeying to using the protection system than other countries as its SRUBH is higher than France and Belgium despite it has lower rate of fatalities than these countries. This can be explained by the significant effect of other factors that have positive role in reducing the rate of fatalities that may related to other unconsidered factors of road user behaviour or related to the vehicle or road infrastructure design. This needs more investigation [34].

7. Conclusions and recommendations

The main conclusions are drawn here with the corresponding recommendation.

a. Developing a composite indicator to assess the road user behaviour and its role in the severity scale of the road safety at country scale is possible. It is needed as a tool of benchmarking the countries according of the road users' behaviour. However, the results show that the considered factors are not the only indictors of the road safety level. This enhances the multidimensional system approach of defining the road safety. Other factors and dimension of the road safety should be considered in conducting research, developing indices of road safety, and in recommending solutions.
b. Developing weighting method based on the saving life is not considered widely. The results of this study show its effectiveness in reflecting the real contributing scale of the considered indicators when there is not sufficient data to use the common statistical used methods. Therefore, it is recommended to investigate this method in further studies.
c. The UK, Sweden, Ireland, and Norway have the best road user behaviour among the selected countries. This reflects the effective road safety legislation and enforcement system. It is recommended to consider their strategies by the road safety policy makers in the other countries to take lessons.

d. More investigation is needed to consider rating methodology and test its validity.

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