

## A Framework for Spatial Road Safety Assessment: Case Study of Northern Ireland

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## A Framework for Spatial Road Safety Assessment: Case Study of Northern Ireland

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### Abstract

Road traffic injuries are a major health issue worldwide. There are many factors that can affect the levels of road traffic collisions which in turn increase the levels of people killed or seriously injured. When road traffic collisions occur, observed facts are recorded in relation to the incident. These facts are recorded as variable observations, and for this study, variables and indicators are defined almost equivalently. There can be hundreds of different indicators for the various collisions, as different countries face different road situations. This makes it difficult to perform a road safety assessment, which can be applied globally. The goal of this study is to select the most appropriate indicators and create a composite indicator as a function of these indicators, which can be used as summary values, allowing ease of comparisons between the countries/regions that have undergone a road safety assessment. The composite indicator will then be used to assess the current situation in Northern Ireland and provide scores for ranking policing in terms of overall road safety on their road networks.

**Key Words:** composite indicator, road safety, assessment.

### 1. Introduction

In 1974 at the world health assembly the World Health Organisation (WHO) declared that road traffic accidents were a major health issue [1]. Prior to this assembly, traffic injuries were not seen as a major health issue and were predominately treated as an issue for the transport sector. This calls for the various government sectors to collaborate in order to increase the efforts currently in place to help reduce the problem of road traffic injuries. In 2002 road traffic injuries were the 2nd leading cause of death for 5-29 year olds and 3rd for 30-44 year olds globally. In 2004 this worsened as road traffic injuries became the leading cause of death for 15-29 year olds, surpassing HIV/AIDS. Road traffic accidents were one of the top 10 main causes of death for all ages greater than 5 [1]. The statistics highlight the growing need for dramatic change in order to improve road safety and thus decrease the number of road traffic deaths.

Time and money need to be invested in relation to road safety in order to develop new and existing strategies in attempt to reduce the number of serious injuries and deaths on the roads. The world report on road traffic injury prevention state that without such efforts and initiatives, the total number of road traffic deaths and injuries worldwide is forecast to rise by 65% from 2002-2020. In low income countries (LIC) and middle income countries (MIC) this is said to increase by 80%.

Road traffic injuries can affect all people, from drivers and passengers of vehicles to vulnerable road users such as pedestrians and motorcyclists. The issue with road traffic accidents is that they are viewed as just that, accidents. This would indicate that they are inevitable and therefore there is nothing that can be done to prevent such incidents. This is untrue as the cause of all road accidents cannot be attributed solely to the road users themselves. In fact there is a wide variety of factors that can effect road safety such as speed and the use of seat-belts to name but a few. Therefore if these factors were investigated and improved, the global road safety could increase so that the rise in road traffic deaths can be combated.

Road safety affects many government sectors, such as health, transport and education. Efforts need to be made in the education sector to educate communities that road safety is something that can be improved upon and that a lot of road accidents can be prevented. In Ireland the department of education is attempting to educate people in order to decrease road accidents. To do this advertisements are created showing sobering scenes of road traffic accidents and the aftermath of such accidents. Examples of advertisements shown are accidents caused by careless driving, driving at speed and driving without the use of seat-belts [2]. The road safety charity Brake [3] hold road safety roadshows with the aim of educating people on road safety. This project focuses on the different factors that affect road safety and thus impact the numbers of road traffic injuries. These factors are known as indicators which evaluate how well an objective is doing.

The overall objective is ultimately the improvement of road safety. As road safety is a global issue and different countries have many different indicators related to road safety. This creates difficulty in comparing results from different countries. Also for those countries that use the same indicators, the units of the indicator or the way the indicator is measured can differ; this leads to indicators that are not standardised, hence making comparisons complex. The goal of this project is to assess the indicators which are currently in use in the UK and Northern Ireland in particular and select the most appropriate indicators and combine them in such a way as to create a composite indicator that can be used as a tool in the assessment of road safety.

This report is organised as follows: there is a discussion constructing a composite indicator for Northern Ireland. Following this is analysis of the results. The report is concluded by a discussion on further work to improve the composite indicator.

## 2. Methodology

In this report, a composite indicator (CI) is constructed using two methods, a rather naïve method and the CI is referred as 'the naïve CI' and the second method constructs the CI by loosely following the steps in the handbook for constructing composite indicators [4]. This method is referred to as the 'handbook CI'. The composite indicator is constructed using data from STATs19. The data consists of 11 variables for 29 policing regions in Northern Ireland in the timeframe 2004 to 2012. The variables are split into three categories: severity of injury, vehicles involved and collisions. Each variable value is the number of times the variable occurred annually, e.g. the number of fatalities in North Belfast.

### 2.1 Naïve CI

The variables are normalised to ensure they are on the same scale to have logical outputs. The normalisation that is applied to the data in the naïve method is shown in equation (1). The choice of the normalisation is to have inputs between 0 and 1 with 0 representing the maximum number of variable values and 1 representing the minimum.

$$y_i = \frac{x_i - \max_i\{x_i\}}{\min_i\{x_i\} - \max_i\{x_i\}} \quad (1)$$

$x_i$  - original values

$y_i$  - normalised values.

The CI is constructed using all of the variables in the dataset. Each variable is added to the model using the same weighting. This method does not take into consideration the relationships between the variables. Equation (2) is the naïve CI, with respect to the  $x_i$  which are the 11 normalised variables in the dataset and  $\frac{1}{11}$  is the weights for each variable.

$$\text{Naive CI} = \frac{1}{11} \sum_{i=1}^{11} x_i \quad (2)$$

Once the composite indicator is built, the results are ranked in ascending order, with the best policing region being the one with the smallest number output from the

composite indicator (a value close to 0). This is true as the model is a linear transformation of the input variables and thus the output variable values  $\in [0,1]$ . The ranking is performed this way as the composite indicator is created from variables that record the number of events, thus the composite indicator with the smallest value is most favourable Figure 1 shows the results of the naïve CI applied to the Northern Ireland data.

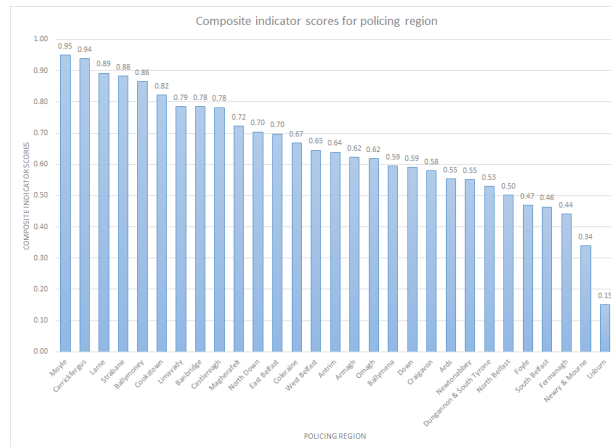


Figure 1: CI scores using naïve CI applied to Northern Ireland data

Obviously, this method has flaws as each variable does not contribute to road safety with the same significance. This naïve approach will be in error for two main reasons: the weights need more thought and cannot be chosen arbitrarily as they have meaning when added to the model and there are too many variables in the model, not all of them are needed as they can be highly correlated.

## 2.2 Handbook CI

This method aims to construct a more appropriate CI with more meaningful results than the naïve CI. For this method, the variables are normalised using an alternative function. The normalisation techniques gives values  $\in [0,1]$  as with the naïve CI but now 0 corresponds to the minimum number and 1 corresponds to the maximum. The normalisation function is shown in equation (3).

$$y_i = \frac{x_i}{\max_i\{x_i\}} \quad (3)$$

The steps from the handbook for constructing composite indicators that are mainly followed are:

Step 2: Selecting variables

Step 3: Multivariate analysis

Step 5: Normalisation of data

Step 6: Weighting & Aggregation

The multivariate technique that is used to find the relationships between the variables in the dataset is the Cronbach correlation coefficient. To assess the correlation between the variables, the correlation coefficient was used in Matlab. The correlation coefficient has values between 0 and 1, with 0 representing zero linear correlation and 1 representing perfect correlation. The data when input to Matlab is in the form of a matrix. Thus the output of the correlation procedure in Matlab is a matrix of correlation coefficients between each of the 11 variables in the dataset. The command used to produce this is:

```
R=corrcoef(M) %M is the matrix of variables values and R is a matrix
of correlation coefficients
```

For each data matrix, different levels (70%, 80% and 90%) of correlation were taken to ensure that the variables were strongly correlated. After analysing the results it was reasonable to take results at 70% correlation as at the higher levels there are very few variables that remain correlated.

At a correlation of 0.7 and above, the number of deaths, the number of fatal collisions and the number of vehicles involved in fatal collisions were correlated (see figure 2 for the correlation matrix). Therefore, only one of the 3 variables will be carried forward to add to the model. The choice of the representing variable is a logical one. From the introduction, it is known that reducing the number of fatalities due to road traffic collisions is an objective of road safety. Thus the number of deaths is the variable that will be added into the model. The second group of correlated variables contains the 8 remaining variables in the Northern Ireland collision dataset:

- Number of serious injuries
- Number of slight injuries
- Number of vehicles involved
- Number of collisions
- Number of serious injury collisions
- Number of slight injury collisions
- Number of vehicles involved in serious injury collisions
- Number of vehicles involved in slight injury collisions

The number of collisions is chosen to be represent all of the variables in this correlated group. The reason for this decision is that without a collision initially occurring, there is no values for the other variables.

Correlation	Number Killed	Number seriously injured	Number slightly injured	Number Vehicles involved	Number collisions	Number fatal collisions	Number serious injury collisions	Number slight injury collisions	Number vehicles involved in fatal collisions	Number vehicles involved in serious injury collisions	Number vehicles involved in slight injury collisions
Number Killed	1										
Number seriously injured	-	1									
Number slightly injured	-	0.740687	1								
Number of vehicles involved	-	0.74145	0.992171	1							
Number of collisions	-	0.763828	0.991521	0.99847	1						
Number fatal collisions	0.989696	-	-	-	-	1					
Number serious injury collisions	-	0.980211	0.833723	0.84258	0.860374	-	1				
Number slight injury collisions	-	0.711578	0.991088	0.997958	0.996926	-	0.818327	1			
Number vehicles involved in fatal collisions	0.977009	0.703531	-	-	-	0.98797	-	-	1		
Number vehicles involved in serious injury collisions	-	0.975937	0.809611	0.821623	0.838435	-	0.994119	0.794616	-	1	
Number vehicles involved in slight injury collisions	-	-	0.989981	0.997328	0.993437	-	0.801738	0.998593	-	0.77820834	1

Figure 2: Correlation matrix for the road safety variables. Only correlations of 0.7 or greater are shown

At the end of these steps, the number of variables has reduced to 2: the number of deaths and the number of collisions. The next step is to find the weights of the variables in order to add them to the model. In the naïve method, the weights were static, in this method the weights are defined by a function to give varying weights. Varying weights seems the better choice as when we consider the relationships between variables. For example, if it is accepted that 10 collisions is equal to 1 deaths, is it reasonable to extend this to have 100 collisions equal to 10 deaths, potentially not. Thus varying weights is more appropriate to use.

In order to create the function, the relationship between the function inputs and function outputs is analysed. The function inputs are the normalised number of deaths and collisions and the function output is the road safety score. This can be written as  $f(x, y)$  where  $x$  is the normalised number of deaths and  $y$  is the normalised number of collisions. To find the function, conditions need to be set-up and satisfied. The conditions that are found are those

that correspond to the limits of the inputs of the function:  $f(0,0)$ ,  $f(0,1)$ ,  $f(1,0)$  and  $f(1,1)$ . Considering  $f(0,0)$ , this corresponds to the minimum number of collisions and deaths which would correspond to maximum road safety.

$$f(0,0) = \max\{f\}$$

Again,  $f(1,1)$  corresponds to the maximum number of deaths and the maximum number of collisions which would represent minimum road safety, hence:

$$f(1,1) = \min\{f\}$$

Evaluating  $f(1,0)$  has the maximum number of deaths with the minimum number of collisions. Theoretically when the minimum number of collisions occur (i.e. 0 collisions) no deaths can occur therefore this condition is equivalent to condition in equation (4)

$$f(1,0) = \max\{f\} = f(0,0)$$

The last set of inputs  $f(0,1)$  corresponds to the minimum number of deaths and maximum number of collisions. An exact output value of the function is unknown at this point but bounds can be put on this condition.

$$f(0,0) \leq f(0,1) \leq f(0,0) = f(1,0)$$

The function that satisfies the inputs in equations (4), (5), (6) and (7) is stated in equation (8) with a graph of the function shown in figure 3

$$f(x, y) = \frac{2(e^{1-x+y} - (1-y)e^{y-(x-1)})}{e^{1-x+y} + (y - (1-x))e^{y-(1-x)}} - 1 \quad (8)$$

The function expressed in equation (8) is the composite indicator for road safety in Northern Ireland. The function takes the normalised number of deaths and the normalised number of collisions for policing region as input. The function has output in range  $[0, 1]$  with 1 indicating maximum road safety relative to the policing regions and an indicator score of 0 representing minimum road safety.

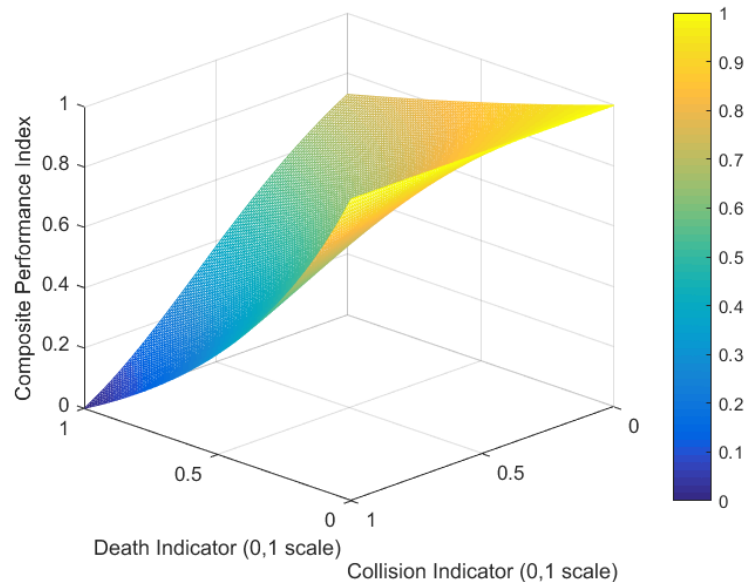


Figure 3: Plot of composite indicator defined in equation (8)

### 3. Discussion of results

In order to get an indication of which policing region is best and which is worst, and everything in between, the naïve CI and the handbook CI are run on the available collision

data per policing region. The naïve CI and handbook CI are also applied to the average collision data, which is taken as the mean of the original data over the available data years.

The main motivation behind constructing a composite indicator is not to solve the road safety problem but to aid identification of the specific problems in relation to road safety. The composite indicator is the first step in trying to improve road safety. From the composite indicator results one can start to make hypothesis on some of the reasons for the overall issue regarding road safety. Once these problems are highlighted, measures can be put in place to improve road safety. Also from looking at patterns of composite indicator results throughout the years, one can attempt to find out the reasons for the change, if any, in the results with respect to policing region. If it is found that one policing regions road safety improved from one year to the next because a new safety scheme was implemented, the idea would be to implement the same scheme in a policing area that needs to improve road safety.

Note that the average data for each policing region is not the arithmetic mean of the composite indicator scores for the nine years. The average score is the score that is calculated when the data is averaged at the very beginning by taking the mean of the original data. By taking the average at the beginning as opposed to the end of the process leads to different average composite indicator results. These discrepancies are caused by the non-linear transformation when the function is applied to the data. Taking the average values at the beginning is the more appropriate approach as the actual real data is being averaged, not the scores.

Whilst making hypothesis based on the results of the CI's, the two methods are compared when applicable. The set of results chosen to be analysed here, are those policing regions which were the top three rated in 2004 (the start of the available data).

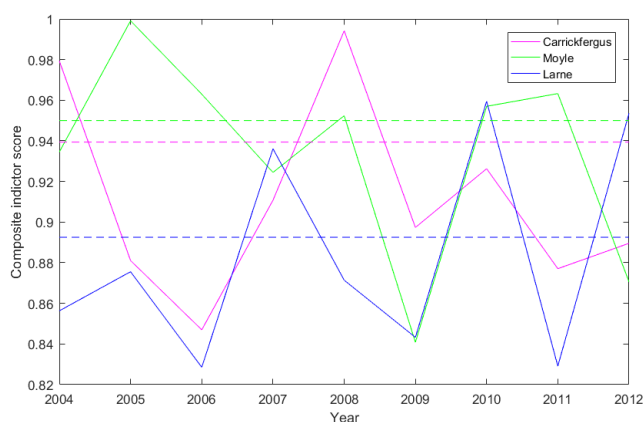


Figure 4: Time graph of naïve CI scores for the top ranking policing regions in terms of road safety in 2004

Figure 5 has the top three policing regions in 2004 according to the handbook CI. These regions are Carrickfergus, Moyle and Larne. From 2004-2005, road safety increased slightly in Larne, from research this can possibly be explained by taking the weather into account. In February 2004, there were strong winds reaching speeds of 70mph which affected mainly Larne and Belfast [5] [6]. This could have improved road safety in this period of time as when weather conditions are bad it may influence driver behaviour in a positive way leading drivers to travel with caution. Also drivers may avoid travelling, thus less traffic on the road leading to less collisions. Also, the A8 Ballynure road which is near Larne was widened in 2004, this could lead to less congestion on the roads and may impact road safety [7].

In 2006-2007, road safety in Larne increased considerably. A skid resistant surface dressing, along with the provision of signs and road markings, were added to the A2 bank road in Larne in July 2006 with the objective of improving road safety [8]. As this is a collision remedial scheme implemented by transport NI, road safety is expected to increase. This

could be the cause for the improvement in road safety in Larne. Also, research showed that ANPR devices were to be installed by 2005, this could have an effect on the road safety, as the devices could act as a deterrent to those who wish to speed or run red lights which could result in collisions. The same scheme could have had an effect on road safety in Carrickfergus and Moyle also but to a lesser extent, as there are peaks in the plot from 2007-2008 for these regions.

In 2008-2009 (2007-2009 for Larne) the road safety decreased dramatically, with Larne and Moyle obtaining their lowest respective CI scores for the nine years. In January 2008 up to 16cm of snow fell which resulted in flooding in many areas in Northern Ireland; including Co Antrim which contains all three policing regions. The flooding occurred again in August 2008 causing 37 major road closures including parts of Antrim [9]. The weather caused havoc again when in December the coldest temperatures were recorded since 1934 affecting many regions in Northern Ireland including Antrim [9]. As the weather was bad near the end of 2008 this could have an effect on road safety at the beginning of 2009. Also a rainfall record was set in November 2009 followed by the coldest December in 30 years [10]. As a result of the terrible weather conditions, one can assume that the road safety was affected, as with cold weather comes icy roads, which should be traversed with caution. This drop in road safety for all three policing regions can be explained by adverse weather. From this conclusion, it is clear that weather effects road safety, thus one of the targets in terms of road safety for the government of Northern Ireland would be to put measures in place to deal with extreme weather.

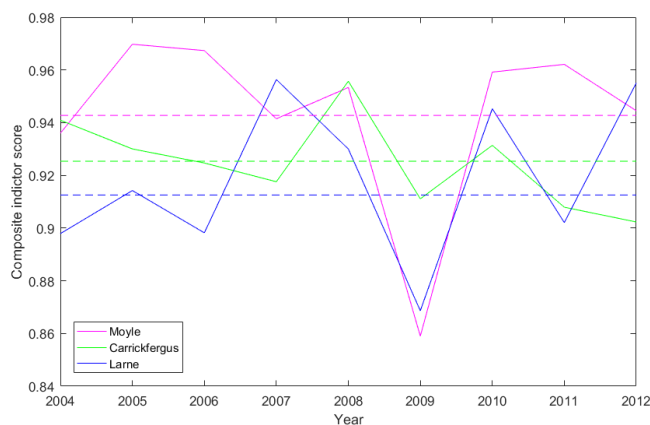


Figure 5: Time graph of handbook CI scores for the top ranking policing regions in terms of road safety in 2004

After this, each of the policing regions had CI scores of above their respective average. This could be due to the CI score of 2009 being such an outlier that the road safety appears to increase. The increase may be a levelling of the scores after the abnormal weather in 2009. In 2012, work began on the A8 dualling with Larne port. This single carriageway roads sees traffic flow of around 18,000 vehicles per day with a large number of freight vehicles coming from the port [7]. With the commencement of work to upgrade this carriageway, one can assume that some of the road was improved by the end of 2012 which could explain why road safety in Larne increased. Also, when road works are ongoing, traffic calming measures are put in place, this can also reduce the risk of collision and hence increase road safety.

Also in March 2011 and April 2011 two traffic calming schemes which involved the implementation of road humps in two areas in Carrickfergus could be the cause for increased road safety in Carrickfergus from 2011 to 2012 [8]. The top three policing regions according to the CI constructed using the handbook do not have constant road safety. Apart from an outlier in 2009 the CI scores are approximately 0.9 or above which implies excellent road safety. Larne policing region has the most fluctuation in road safety year on year. With Carrickfergus having the least deviation from their average. The top three policing regions using the scores from the naive CI are the same as that for the handbook CI. The rank of these policing are also the same in 2004 and 2012.



From this, there is no evidence that the handbook method is a better method than the naive method. One difference between the two methods is that the range of CI scores using the naive method is larger than that of the handbook CI. As the regions are the same, the explanations for the road safety changes in figure 4 are the same as that for figure 5. See above. From the results of the CI for both methods, the main causes of the changes in road safety for the high performing policing regions are due to weather and roadworks.

#### **4. Conclusions and Further Work**

The results using the two methods for constructing composite indicators give very similar results. On average the two methods give the same top three policing regions with Moyle as the safest policing region on average, with an average score of 0.94 and 0.95 for the handbook CI and the naïve CI respectively. The same is true for the bottom two policing regions. Larne is ranked the most unsafe region with Newry & Mourne the second worst with handbook CI and naïve CI scores of 0.2, 0.15 (Lisburn), 0.21 and 0.34 (Newry & Mourne). The differences come from the intermediate policing regions as when one looks at those, differences start to emerge. From this one can conclude that the handbook CI is a better CI than the naïve CI but only marginally. Further work needs to be taken to improve this method. The analysis of the composite indicator results produced by both methods found that road safety fluctuates a lot year on year. Weather appears to be a major cause for both positive and negative changes in road safety. With collision remedial schemes and traffic calming schemes appearing to be a potential cause for the positive changes in road safety. The difficulty in the analysis was the availability of information. As information was lacking for a subset of the policing regions, a thorough analysis could not be performed, which means that all causes of changes in road safety could not be found.

Further work that can be performed would be to potentially add variables to the model that are found to affect road safety, such as population density, drink/drugs driving and speeding.

#### **Acknowledgements**

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