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**Summary:**

# Injury severity density

## A new approach to identifying hazardous road sections

This report presents a new approach to identifying hazardous road sections in Norway. The new approach relies on a concept called "injury severity density". Injury severity density denotes the number of injured road users on a section of road, weighted by the societal costs of the injuries. By weighting the number of injured road users by the cost of the injuries, more weight is given to fatal and serious injuries than to slight injuries.

## Definition of injury severity density

Injury severity density (ISD) is defined as follows:

$$\text{ISD} = \frac{33.20FAT + 22.74CRI + 7.56SER + 1.00SLI}{Km * year}$$

FAT = fatally injured road users (death within 30 days of accident)

CRI = critically injured road users

SER = seriously injured road users

SLI = slightly injured road users

These are the levels of injury severity used in official Norwegian road accident statistics. For the country as a whole, about 2-3% of all injured road users recorded in official statistics are fatally injured, about 1-2% are critically injured, about 8-12% are seriously injured, and about 85-90% are slightly injured. The total number of injured road users amounts to about 12,000 per year. In the above definition, km denotes kilometres of road and year denotes the number of years for which accident statistics are used in estimating injury severity density.

The weights assigned to each level of injury severity (33.2 – 22.74) represent the costs to society of one injury of the stated severity. It is seen that one fatal injury is given 33.2 times the weight of one slight injury. This means that fatalities count more heavily than their numbers alone would imply in estimating injury severity density.

## Three estimators of injury severity density

In the report, a distinction is made between three estimators of injury severity density:

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1. Recorded injury severity density (RISD), which is estimated on the basis of the recorded number of injured road users for a given road section.
2. Normal injury severity density (NISD), which is estimated by fitting a multivariate statistical model representing the effects of factors that influence the number of injured road users.
3. Expected injury severity density (EISD), which is estimated as a weighted mean of recorded and normal injury severity density, and which is an estimate of the long-term expected value of injury severity density for a given road section.

This approach to estimation is known in the literature as the empirical Bayes approach to the estimation of road safety. The most important reason for relying on the empirical Bayes approach when estimating injury severity density, is the fact that the recorded number of injured road users for a given road section may be strongly influenced by random variation. Estimates based on the recorded number of injuries only would therefore exhibit large and seemingly inexplicable fluctuations from year to year or from one road section to another when comparing similar road sections.

The empirical Bayes approach to road safety estimation is based on the assumption that there are two main sources of information about the long-term expected number of accidents or injured road users for a given road section. One source is general knowledge of factors that influence the number of road accidents or injured road users. The other source of information is the recorded number of accidents or injured road users for a certain road section.

## Model to estimate the normal expected number of road users killed or injured

The multivariate models developed in the report are all negative binomial regression models. The models rely on data covering eight years and referring to 1-kilometre road sections. In a few cases, data referring to shorter periods (not less than four years) or to shorter road sections (not shorter than 0.5 kilometres) have been used. Separate models have been fitted to explain variation in the number of fatally injured road users, the number of critically injured road users, the number of seriously injured road users and the number of slightly injured road users. Each model estimates the effects on the number of injured road users of the following explanatory variables:

1. Annual average daily traffic (AADT; a continuous variable)
2. Speed limit (50, 60, 70, 80 or 90 km/h)
3. The type of road, for road that have a speed limit of 90 km/h (motorway class A, motorway class B, other road)
4. Number of lanes (1, 2, 3, etc)
5. Number of junctions per kilometre (0, 1, 2, etc)
6. Whether the road has the status of a national main road or not (yes/no)

The output of the models fitted is a set of equations that can be used to estimate the normal number of fatally injured, critically injured, seriously injured or slightly injured road users for any combination of values for the explanatory variables.

## Combining the normal and recorded number of killed or injured road users

When the normal number of injured road users, specified according to injury severity, is known for a road section, it is combined with the recorded number of injured road users to form an estimate of the expected number of injured road users. Combing the normal and the recorded numbers of injured road users is a key element of the empirical Bayes approach. Empirical Bayes estimates of road safety have two advantages compared to traditional estimates based either on the recorded or the normal number of accidents or injured road users:

1. Random variation in the recorded number of injured road users is eliminated. In this way, the effects of regression-to-the-mean are removed from the recorded number of injured road users.
2. The effects on the number of injured road users of local factors not included in the multivariate models are captured. In this way, account is taken of the fact that roads that are similar in terms of traffic volume, speed limit, number of lanes, and so on, may differ in terns of other factors that influence their safety.

The report describes the theoretical basis of the models developed and their estimation in technical terms. These technical details will not be referred to in this summary.

## Identification of hazardous road sections

The results of the analyses are intended for use in identifying hazardous road sections in Norway. The report explains in detail how to estimate injury severity density for a given road section, and how to interpret the results.

The Public Roads Administration has made a preliminary classification of national roads in three classes according to injury severity density:

1. Red roads, defined as roads where expected injury severity density exceeds 1.2 and accidents resulting in fatal or serious injury have been recorded during the last eight years. These roads comprise about 10% of national roads.
2. Green roads, defined as the safest 50% of roads according to expected injury severity density, and with the additional condition that no fatal or serious injury accidents should be recorded during the last eight years.
3. Yellow roads, which are the remaining 40% of national roads that do not satisfy the criteria for being red or green.

The report discusses in general terms how best to identify hazardous roads on the basis of injury severity density. It is concluded that expected injury severity density is the best criterion. The ratio EISD/NISD can be used as a supplementary criterion, for the purpose of identifying roads where local risk factors contribute substantially to injury severity density. The larger the contribution of local risk factors, the higher will be the ratio EISD/NISD.

The model developed in this report will be used as a basis for more detailed accident analyses for specific road sections.