Summary

Handbook of Road Safety Measures – Background information about crashes, risk, and meta-analysis

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The Handbook of Road Safety Measures summarizes results from empirical studies that have investigated safety effects of different types of road safety measures. As far as possible, results are summarized by meta-analysis. The present report contains the introductory part of the Handbook. A short version is published in the online version of the Handbook at tsh.toi.no. The report presents some background information, including a summary of vision zero, general information about crashes and crash risk in Norway and internationally and an overview of crash costs and cost-benefit analysis. It also contains an introduction to meta-analysis, including guidelines for systematic reviews and the basics of the most important statistical methods in log odds meta-analysis and analysis of potential biases.

Background

» Contents and structure of the Handbook of Road Safety Measures

This report contains background information about the Handbook of Road Safety Measures. The Handbook of Road Safety Measures contains the following ten chapters, each containing subchapters about specific road safety measures:

1. Road design and road equipment
2. Road maintenance
3. Traffic control
4. Vehicle design and protective devices
5. Vehicle and garage inspection
6. Driver training and regulation of professional drivers
7. Public education and information
8. Enforcement and sanctions
9. Post accident care
10. General-purpose policy instruments

Each of the subchapters describing specific road safety measures contains the following sections:

Problem and objective. This section describes the road safety problem which the measure is designed to solve or reduce. A road safety problem can be described in terms of a high number of accidents, a high accident rate or a high proportion of serious injuries. However, not all road safety problems can be described exhaustively in numerical terms only. This applies, for example, to the feeling of insecurity that some road users experience. Some of the measures described in the Handbook have primarily other aims than improving road safety, such as reducing travel times or improving conditions for walking and cycling.

Description of the measure. This section gives information concerning the design of a road safety measure and its intended function. The main focus is on how a measure is used in those evaluation studies that are summarized in the section about crash effects. Detailed technical descriptions are not given.

Effect on accidents. This section deals with the effects on accidents, or on the severity of injury in accidents, which have been found in research. Effects are stated in terms of the percentage change of the number of accidents or injuries, based on systematic reviews and, whenever possible, meta-analysis. Confidence intervals and the most important sources of uncertainty are described as well. For measures where no studies have been found that quantify effects on road safety, qualitative reviews are conducted.

Effect on mobility. In addition to the effect on accidents and injuries, many road safety measures also have effects on mobility. These impacts are briefly described, but not in as great detail as safety effects.

Effects on the environment. Effects on the environment are briefly described. Such effects include traffic noise and air pollution in a wide sense of these terms. Major incursions into the landscape and changes in land use should also be regarded as important environmental effects.

Costs and cost-benefit analysis. For the majority of measures, information is given regarding the cost of the measure in Norway. Cost-benefit analyses are presented whenever available. However, the results of cost-benefit analyses depend strongly on the context to which they refer. Monetary valuations of impacts, which are a key element of cost-benefit analysis, vary substantially between countries. As a rule, one would therefore not expect the results of cost-benefit analyses made in one country to apply directly to another country. The context to which most of the analyses presented refer, is the current situation in Norway.

Crashes and risk in road transport

» Reporting and underreporting of crashes

Most studies of the effects of road safety measures on crashes are based on official crash statistics. Such crash statistics are for the most part quite reliable as regards the most serious crashes. However, certain types of crashes can be highly underreported, especially slight injury crashes, crashes with vulnerable road users, and single vehicle crashes.

In Norway, all crashes involving vehicles (mainly motor vehicles and bicycles) that involve personal injury, have to be reported to the police. It is estimated that 17% of all road traffic crashes actually are reported. The reporting rate is lowest for slight injuries (15%), higher for serious injuries (below 37%) and highest for fatal injuries (close to 100%). Pedestrian accidents without vehicles involved are not included in official crash statistics. Property damage only crashes are not included either. However, there are registers both in Norway and other countries that include such crashes.

» Risk in Norway compared to other countries

Crash risk in road traffic is relatively low in Norway compared to other countries with similar numbers of motor vehicles per inhabitant. Norway has had this leading position for many years, including earlier years when there were far more killed or seriously injured in road traffic than today.

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Among the contributing factors to the low crash risk in Norway are low speed limits, strict drunk driving laws, and a relatively high use of seat belts. On the other hand, Norway has few motorways and a highly varying standard on the remaining road network. In Norway decisions concerning road safety are to a relatively large degree based on research. Thus, there are good chances for implemented measures to be effective.

» Factors affecting crashes and crash severity

Numbers of crashes and injuries depend on the following three general factors:

- *Traffic volume:* Increasing volumes are usually associated with increases and crash numbers. However, crash numbers (especially injury crashes) usually increase less than proportional with volume. In other words, crash risk for each individual road user is lower on average at higher volumes.
- *Crash risk:* Crash risk is the average number of crashes per travelled kilometer. Factors that affect crash risk include, amongst other things: The of vehicle, road type, road design, environmental factors (such as light and weather conditions), and factors related to the road user (such as age, gender, intoxication, fatigue, and distraction).
- *Injury risk:* Injury risk is the average number of injuries per crash. Factors that affect injury risk include, amongst other things: Speed, type of vehicle, factors related to the road user (especially age), use of protective equipment, and post-accident care.

» Crashes and risk as measures of road safety

Road safety can be defined in different ways in terms of crash or injury numbers. The most important approaches are described in the following.

Expected crash numbers: The expected number of crashes (or injuries) is the average number of crashes per unit of time that (theoretically) can be observed in the long run, assuming unchanged volume and risk. Road safety evaluations are ideally based on expected crash numbers. The observed number of crashes per unit of time (for example one year or four years) is not necessarily an appropriate estimator of the expected number of crashes because of random variation. For example, when a road safety measure is implemented at the end of a period with exceptionally high crash numbers (for example one or two years), crash numbers will most likely decrease during the next one or two years, even without any safety measure. This effect is called regression to the mean. There are statistical methods for controlling for regression to the mean.

Crash risk: Crash risk (or injury risk) is defined as the number of crashes (or injuries) per unit of exposure. Exposure is often defined in terms of millions of vehicle or person kilometers. When crash risk is used as the dependent variable in road safety evaluations, one assumes implicitly that the number of crashes changes proportionally with exposure, all else being equal. This assumption is not always correct. Increasing exposure is often related to a reduction in risk. For example, as the amount of cycling increases, risk has been found to decrease for each individual cyclist in a number of studies. This is the so-called safety-in-numbers effect. Motor vehicle crashes also tend to increase less than proportional with exposure. Ignoring such relationships may lead to biased results of road safety evaluations.

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Health risk: Health risk as a measure of road safety is defined as the number of killed or injured persons in road traffic per 100.000 population per year. Health risk does not take into account any kind of exposure measure. It does therefore not say anything about how dangerous it is to participate in road traffic. For example, a highly motorized country can have a high health risk, despite low crash risk. Countries with very little road traffic may have low health risk, although those that are participating in road traffic have a very high risk.

The quality of studies of the effects of road safety measures

The primary goal of road safety evaluations is to find out if a measure can be expected to reduce the expected number of crashes or injuries or if it reduces crash or injury risk, compared to a situation without the measure in question. This section describes the requirements empirical studies should meet in order to be able to answer such questions.

» Validity: Methodological quality and causal inference

In short, study validity denotes the degree to which the results of the study approximate the truth. The criteria of study quality that have been applied to assess the road safety evaluation studies referred to in this book, are to a great extent based on the validity framework of Cook and Campbell (1979). According to this framework, the quality of a study can be assessed in terms of four types of validity that are described in the following.

Statistical conclusion validity refers to the accurateness and the representativeness of the data and the results of statistical analyses in a study. Study results are statistically valid if they cannot be attributed to randomness or bias of the measurements and if they are representative of a known population of units. The statistical conclusion validity of road safety evaluations can be assessed in terms of the following criteria:

- Sampling technique
- Sample size
- Reporting of statistical uncertainty in results
- Measurement errors
- Specification of accident or injury severity.

Theoretical validity, or construct validity, refers to the theoretical foundation and to the operational definition of theoretical concepts and propositions. A study is theoretically valid if the study measures what it intends to measure and if the results can be explained in terms of theory. Criteria for theoretical validity are:

- Identification of relevant concepts and variables (such as moderator, mediator, and confounding variables)
- Hypotheses describing the relationships between variables
- Knowledge of causal mechanism.

Internal validity refers to the inference of a causal relationship between treatment and effect. This aspect of study validity is very important because the objective of a road safety evaluation study is to determine the *effects* on safety of a road safety measure, not the coincidence of a safety measure and some safety indicator. The following criteria indicate that there is a causal relationship between a safety measure A and a safety indicator B:

- Statistical association between treatment and effect
- A clear direction of causality
- A dose-response pattern (where this is relevant)

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- Specificity of the effect (an effect is found in the target group of the measure, not in other groups)
- Control of confounding factors (other safety measures or other changes that coincide in time with the safety measure under evaluation, regression to the mean, self-selection bias, crash migration, study effects)
- Control for endogeneity (if a safety measure is implemented at sites with above average crash numbers)
- Correct specification of the functional form of the relationship between an independent variable (usually a road safety measure) and the estimator of safety effect (relevant in multivariate studies)
- No bias attributable to collinearity or omitted variables (too many, highly interrelated, or too few predictor variables a multivariate model).

External validity refers to the generalizability of study results. A study has high external validity if its findings are valid for different settings than those in which the study was made. It is difficult to assess the external validity of a single study. External validity is best assessed by comparing the findings of studies that have been made in different settings. However, context specific effects of safety measures are not necessarily a methodological weakness, but rather a property of reality. Nevertheless, context specific effects reduce external validity. To some extent, high external validity can make up for the absence of a strong theoretical foundation for road safety evaluation studies. Results that have been replicated a large number of times, in many studies made in many countries, are more likely to show true effects than results reported by just a few studies in just a few countries.

» Assessment of methodological quality in the Handbook of Roads Safety Measures

All studies included in meta-analysis in the Handbook of Road Safety Measures are assessed with respect to methodological quality. Whenever possible, it is also investigated to what degree the results are affected by methodological weaknesses, for example by comparing results between methodologically strong versus weak studies. If methodological quality varies and if it is found to affect the results, only the methodologically best studies are selected for meta-analysis. Simple before-after or simple case-control studies (without any control for confounders) are generally not included in meta-analysis.

If only weak studies are available, the results are presented as they are, but potential effects of methodological weaknesses are discussed. Additionally, results from studies that have investigated effects on indirect measures of safety may be included in the presentation, such as behavior and conflict studies. Ideally, only results from experimental studies would be included in meta-analysis. However, such studies are seldom possible in the field of road safety.

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Conducting systematic reviews for the Handbook of Road Safety Measures

» *Literature search*

The Handbook of Road Safety Measures is based on systematic reviews of international studies of the effects of road safety measures on crashes and injuries. The reviews are based on searches of scientific databases (such as ISI Web of Knowledge, TRID), other data bases (such as ScienceDirect, Taylor & Francis online, TRB, PubMed) and the internet (Google Scholar). The reviews are primarily based on the PRISMA check list by Moher et al. (2009, 2015).

The main focus is on studies that have reported quantitative results describing the effects of a safety measure on the number of crashes or injuries, or on crash or injury risk. Studies that have investigated effects on indirect safety indicators, such as conflicts or behavior, are mainly used for safety measures that have not been evaluated in crash studies. They may also be used when results from crash studies are highly inconclusive or contradictory.

» *Meta-analysis*

As far as possible, results from empirical crash studies are summarized by means of meta-analysis in the Handbook of Road Safety Measures. Meta-analysis implies that weighted averages are calculated for a measure of effect that is reported from several studies for a specific road safety measure. The following aspects of the results from individual empirical studies can be investigated by means of meta-analysis:

- *Percentage change of the number of crashes or injuries:* The main results from meta-analysis are reported as percentage changes of the number of crashes or injuries. Ideally, they refer to expected crash/injury numbers.
- *Confidence intervals:* The statistical uncertainty of the results is reported as 95% confidence intervals. A confidence interval is the interval which in 95 % of the cases would contain the true value of the effect if the same study had been conducted an infinite number of times under the same conditions, provided that the true effect is equal to the one found in the current study (or meta-analysis). Large confidence intervals imply large uncertainty. Large uncertainty in meta-analysis can be due to large uncertainty in the individual studies or large differences between the results of the individual studies. The practical significance of a result depends not only on statistical significance (whether the confidence interval does not “no effect”), but also on the size of the effect and its validity.
- *Methodologically strong vs. weak studies:* The statistical uncertainty (the size of the confidence intervals) is directly not affected by the methodological quality of the individual studies. Therefore, meta-analyses in the Handbook of Road Safety Measures are as far as possible based on the methodologically strongest studies. Whenever possible, it is also investigated systematically if the methodological quality of individual studies is related to the results, for example by subgroup-analysis or meta-regression.
- *Publication bias:* The individual studies that are included in meta-analysis may be a biased selection of all potential studies that exist, or may exist, for a given road safety measure. The reason is that studies with unexpected, undesired, or non-significant results often remain unpublished. Whenever possible, it is investigated systematically to what degree the results of meta-analysis may be affected by publication bis or other types of bias that may lead to similar effects.

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- ***Moderator variables:*** Road safety measures may have different effects, depending on specific characteristics of the measure or circumstances under which it is implemented. In most meta-analyses in the Handbook of Road Safety Measures it is investigated systematically if there the results may be affected by moderator variables that can be defined on study level. If any such variables are identified, results are reported for the different levels of these variables. Typical study level moderator variables are crash type, crash severity, road type, and road user group (for example by age or gender).

The Handbook of Road Safety Measures presents for the most part only short summaries of the most important results from meta-analysis. More detailed results are described in working documents (unpublished, available on request), TØI-reports, and, as far as possible, in scientific journals.

Cost-benefit analysis

The aim of cost-benefit analysis is to provide information about the cost-effectiveness of a measure or if its benefits exceed the costs. In cost-benefit analysis benefits and costs are assigned monetary values. Cost-effectiveness can be expressed in terms of:

- Net present value: The difference between benefit and costs of the measure; it is positive if benefits are greater than costs
- Benefit-cost ratio: The benefit divided by the cost of the measure; if this ratio is larger than one, the measure is cost-effective.
- Net benefit per unit of public expenditure: The net present value (benefits minus costs) divided by public expenditures. If this ratio is greater than zero, the measure is cost-effective.

Factors included in cost-benefit analyses of road safety measures are mainly:

- Road user benefits: These include changes in travel time, vehicle operating costs, feeling of insecurity and public health
- Transport operator benefits: These are costs and benefits to public transport operators, toll scheme operators, ferry companies and parking companies
- Budgetary impacts: These include investments, maintenance and operation and income from taxes
- Road accidents: Costs of injury accidents and property damage accidents; the dominant item is willingness-to-pay for reduced risk of death or injury
- Opportunity cost of taxation (loss of efficiency)
- Noise and air pollution.

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