

Summary:

Towards a general theory of the relationship between exposure and risk

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Author: Rune Elvik

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The report proposes a new definition of exposure to the risk of accident in road traffic. Exposure is defined as any event, limited in time and space, that has the potential of becoming an accident and places demands on road user cognition. Events are countable; thus their total number can be regarded as a sampling frame (population) from which accidents are sampled with a certain probability. Risk is defined as the probability of accident, which is simply the number of events of a given type that have an accident as their outcome. These definitions of exposure and risk re-establish the connection between the basic concepts of accident research and probability theory.

This report is a contribution towards a general theory of the relationship between exposure and risk. It is a first attempt to develop the key concepts of such a theory and illustrate some of the insights it can give.

Problems of the conventional use of the concepts of exposure and risk

Historically, the key concepts of accident research, exposure and risk, were derived from the concepts of trials and probability, as defined in the field of probability theory. A trial was any random event that had an accident as one of its outcomes. The probability of an accident was the proportion of trials that had an accident as its outcome. Modern summary measures of exposure, like AADT, annual driving distance or vehicle kilometres of travel, cannot be interpreted as trials in the classic sense of the term. The commonly used indicator of risk, accidents per million units of exposure, cannot be interpreted as a probability and may not even be positively related to it. Thus, as conventionally used today, the concepts of exposure and risk have lost their connection to probability theory. This means that one cannot assume that the product of exposure and risk produces unbiased estimates of the long-term expected number of accidents. In particular, the increasing understanding that risks are non-linear (i.e. depend on the amount of exposure) completely invalidates the use of accident rates to control for the effects of exposure on the number of accidents.

Redefining exposure and risk

This report proposes new definitions of exposure and risk. Exposure is defined as any event, limited in time and space, that has the potential of becoming an accident

and places demands on road user cognition. The latter part of this definition, referring to human cognition, is not normally part of the definition of exposure, but has been included because any event producing the potential for an accident is the result of human behaviour and requires action by road users to control it so that it does not become an accident. This may change if fully automated driving becomes a reality.

Events have limited duration and spatial extent. Their beginning and end can be defined precisely enough to allow events to be counted. The total number of events can be regarded as a sampling frame (population) from which accidents are sampled with a certain probability. Risk is thus defined as the proportion of events that have an accident as the outcome.

Events generate a potential for accidents by bringing road users close to each other in time and space, or by requiring the road user to take action to avoid leaving the roadway. The following elementary types of events are proposed:

- Encounters, i.e. vehicles or road users passing each other in opposite directions of travel with no physical barrier to separate them
- Simultaneous arrivals at points where conflicts between road users may arise (junctions, pedestrian crossings)
- Turning movements in junctions (involving road users who did not necessarily arrive at the same time)
- Braking events
- Lane changes on multilane roads
- Overtakings, i.e. one vehicle passing another vehicle travelling in the same direction
- Negotiating horizontal curves

An event typically last a few seconds. For some of the events listed above, their number can be calculated from summary measures of exposure, like AADT. In the future, however, it is likely that motor vehicles will have technology that can recognise the events and be able to count them if technology for this purpose is part of the event-recognising systems. There is already on the market vehicle technology that monitors braking (intelligent cruise control), lane-keeping (related to encounters and running-off-the-road) and blind spots when changing lanes. These systems are probably only the beginning of more comprehensive, integrated systems that can monitor most aspects of traffic. To redefine exposure in terms of specific events is therefore future-oriented and allows for a vastly more detailed study of exposure than current summary measures, like vehicle kilometres. Vehicle kilometres are, essentially, a black box and tell nothing about what happened along any kilometre driven.

Exposure as learning

The repeated experience of a certain type of traffic event will be associated with learning, i. e. road users will become more and more competent in understanding and controlling the events so that they do not result in an accident. In general, therefore, one would expect there to be a negative relationship between exposure and risk. The larger the number of events of a given type, the lower the risk of accident. Hence, even when exposure and risk are redefined as proposed in this report, it will, in

general, not be correct to estimate the expected number of accidents by multiplying exposure with risk. By contrast, the non-linearity of the relationship between exposure and risk must be modelled explicitly. The main task in developing a general theory of the relationship between exposure and risk is to propose specific hypotheses regarding the shape of this relationship. Some hypotheses are proposed in this report, but they should be seen only as a first attempt to develop a theory.

Review of empirical studies

Selected empirical studies of the relationship between exposure and risk are reviewed in the report. These studies all support the strong non-linearity of the relationship. One should, however, not regard the review of studies as a test of the hypotheses proposed in a stringent sense of the term. All the studies that have been reviewed are based on summary estimators of exposure, not the event-based concept of exposure proposed in this report. Testing the hypotheses proposed in this report requires data on the number of events of specific types. As noted above, it is likely that such data will be available in the future.