4. A FRAMEWORK FOR THE PREDICTION OF THE ROAD-SAFETY EFFECTS OF NEW TECHNOLOGY

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ABSTRACT

This paper describes a framework for the prediction of the net safety effects to be obtained by the introduction of safety directed devices in the road traffic system.
The framework comprises four interacting components:

(1) The 'engineering estimate' of a device's expected safety effect.
(2) The use rate of the device.
(3) Behavioral adaptation by the user.
(4) The functions relating user behavior to accident probability and severity.

Definitions of these components are given, and initial assessments are given of what quantitative evidence is available to base reliable predictions on. The paper concludes with an inventory of research activities that should lead to the implementation of the framework.

4.1 INTRODUCTION

This paper describes a framework for the prediction of the net safety effects to be obtained by the introduction of safety-directed devices in the road traffic system. Net effects in this approach are seen as originating from the interaction of four different components, and reliable predictions can follow if reliable quantitative information on each of the components is available.

Expected safety effects of new technology are presently derived from what is probably best described as the combination of more or less quantitative, empirically obtained evidence with expert judgement (e.g., Neumann, 1991). The latter seems particularly predominant when it comes to the assessment of what probably should be considered to be the core element determining net safety effects, which is the reaction of users - in the form of behavioral changes - to the availability of new forms of assistance.

The motivation for introducing the present framework is our conviction that a sufficiently large knowledge base now exists in traffic safety science to begin to fill the different relevant components, including induced behavioral changes, with the required quantitative information. Before actually undertaking to do so, however, the format of the required knowledge needs to be defined, and this is what we will do in the present paper.

4.2 COMPONENTS OF THE FRAMEWORK

There are four critical components which, together with their interrelations, comprise the framework to be developed, and which should be specified. These are:

(1) The so-called 'engineering estimate' of a device's expected safety effect, that is the accident reduction to be achieved if 100% of the relevant population had the device and if that population showed no behavioral adaptation whatsoever to the new situation, i.e., *with* the device.
(2) The degree of penetration, or use rate, of the device in the relevant population.
(3) The behavioral mechanisms underlying a road user's response to changes in his task environment brought about by, e.g., the implementation of safety-directed technology.
(4) The functional relationships linking parameters of (driver) behavior to resultant accident probability and severity.

This paper is not intended to derive the specifications for these components themselves, but rather to sketch the *format* of specifications, that is how they must look like and what kind of knowledge needs to be assembled before they can actually be put together.

4.3 THE ENGINEERING ESTIMATE

The basic notion in making an engineering estimate is that expected safety benefits are given as an extrapolation or an implication of a rather straightforward engineering calculation. By doing so, physical changes to the system are considered without initially addressing possible induced user change. For example, if design changes to some roadside device would be calculated by engineering methods to reduce the probability of a driver death on impact by 10%, then the engineering estimate is that a 10% reduction in driver deaths from collisions with the modified device will occur.

The most common way to obtain an engineering estimate is indeed from accident data. A device that, according to accident statistics, causes x % of deaths is expected to yield a safety return of x % upon its removal. Alternatively, if the absence of a device would lead to y % of all deaths, then the implementation of that device would be expected to reduce deaths by those same y %.

In other cases an engineering estimate can be made on the basis of laboratory results, e.g., for hardware devices tested under crash conditions representative of those occurring in reality. In still other cases the engineering estimate can be no more than the expectation of a beneficial safety effect, or an order of magnitude thereof.

The prediction of safety effects can never be better than the engineering estimate permits. That is, each and every safety measure needs an estimate of its effect *per se* when its implementation is being considered, and against which the effect that is ultimately realized must be evaluated. The ideal therefore is that there be extremely little uncertainty in the engineering estimate. We are aware that this ideal will not be achieved in a long time, so that we will most often have to resort to relatively crude estimates of a measure's effectiveness.

4.4 USE RATES

In order to be able to assess a device's effectiveness we must know which part of the relevant population is affected, i.e., how large the device's degree of penetration, or use rate, is.

For safety-directed measures which for their effectiveness rely on the acceptance of the population there is the complicating and complex issue of selective recruitment, meaning that the use rate *per se* as well as the effect that is achieved are affected by self-selective processes in the population. The hypothesis is that those who opt for some safety device differ from those who do not in respects that are essential to its effectiveness, the particular assumption being that those the least inclined to accept a safety measure would profit the most from it (Evans, 1985). Useful quantitative expressions describing the implications of self-selective processes for driving behavior as well as for resultant accident involvement rates have been derived by Evans (1987a,b).

An important issue, preceding the incorporation of self-selective behavioral effects in quantitative form, is what it is that makes some people opt for a safety measure and some not. This is an aspect that is not captured in Evans' expressions, but that must eventually be considered in order to make quantitative predictions of expected use rates.

4.5 THE AVAILABILITY OF A BEHAVIORAL MODEL

People respond and adapt to changes in their environment. There is no reason why they should not do so after the environment has been changed by safety-directed technology. A sensible behavioral model should incorporate this fact either explicitly or as a consequence of its internal build-up.

What is it that people change in their behavior? There is no need to assume that *risk*, however defined, is the variable directly controlled by people taking part in traffic. Instead, an accepted risk level may be no more than a more or less epiphenomenal by-product of decision making balancing several positive and negative factors (utilities) associated with a trip.

Models that permit the quantitative derivation of risk levels maintained by traffic participants as a result of a more general decision making process, and that can incorporate the effects of safety measures, are rare. Risk homeostasis theory (RHT) as developed by Wilde (e.g., 1982, 1988) is the primordial theory in this respect. However, RHT does not contain the critical quantitative expressions that link the relevant variables. O'Neill's model (1977) is an important step in that direction, since it contains quantitative expressions for the choice of at least one parameter (speed) a driver will select which has straightforward implications for accepted risk levels. Janssen and Tenkink (1988) have followed up O'Neill's work with somewhat more detailed considerations.

We expect that models that consider utility considerations as central can capture the essence of behavioral adaptation, that is, the replacement of one form of behavior by another because there is some extra utility to be gained, the consequence being that the reduction in risk offered is to some degree absorbed into improved mobility.

One implication of these models that should be mentioned here is that they could actually imply that mobility, in terms of VMT, could rise as a consequence of having a device that offers more safety per km driven. Thus, while VMT is usually seen as an independent input factor affecting road safety the position is defendable that it is at least partially the other way round. Other higher-order aspects of behavior that will likely be affected, and that will have to be modeled at some stage if realistic safety effects are to be estimated, are in modal split (changes from one mode of transportation to another) and in route choice, given that one already has decided to reach a certain destination by motor vehicle.

4.6 THE RELATION BETWEEN BEHAVIOR AND SAFETY

One more element remains to be specified within the framework, which is the nature of the functions that link parameters of driver behavior to resultant accident probability and severity.

This relationship is more or less known for driving speed, and for its variability (e.g., Nilsson, 1984; Koornstra, 1990). Quantitative knowledge also exists for car-following headways (e.g., Evans & Wasielewski, 1983), though not in a complete functional form. Considerably less is known in quantitative form about interactions between traffic participants and consequent accident risk.

If there is one thing we need in traffic safety science it is the determination of more of these functions and the validation of those that we already have some knowledge of. Nevertheless, there *is* a quantitative basis of knowledge that covers both the free flow situation (where speed is at the driver's discretion) and the restricted flow condition where almost your only choice is how closely to follow your leading vehicle.

4.7 TOP DOWN AND BOTTOM UP THROUGH THE FRAMEWORK

The framework as it has been presented here is not unidirectional in the sense that a certain piece of technology should be available first, after which its effects can be followed through to the very end by applying the theoretical machinery. It is equally possible to start in the middle and work both ways, i.e., to the beginning as well as to the end. For example, questions can be answered like whether it is more worthwhile to design a device that is assumed to take away the top end of free speed distributions or one that is assumed to reduce very short headways under restricted flow conditions. Answering a question like this requires the entire framework, i.e., the production of an engineering estimate (presumably derived from accident statistics), a prediction of the type and levels of behavioral adaptation that will occur for each separate device, as well as the use of the known functions relating parameters of driving behavior to accident risk.

4.8 DISCUSSION AND RECOMMENDATIONS

In this paper we have identified and described the components of a framework that we will believe are necessary and sufficient in permitting us to predict the net effects of the introduction of safety-directed devices in the road traffic system. We have also indicated initial assessments of the type and the amount of knowledge already available for application within the framework.

It is clear that gaps in knowledge still exist, in particular in trying to get a reliable hold on engineering estimates and on the use rates to be expected. However, it is also clear that there is sufficient knowledge in relevant areas waiting to be applied and integrated in order to replace, refine, or at least complement existing methodology for assessing expected safety effects.

The programmatic effort that would be required to explore the implications of what we have said would comprise the following:

(1) The detailed quantitative specification of the separate elements of the predictive framework and of their interrelations.

(2) The validation of the approach by its application to road-safety measures that were already introduced in the past, i.e., of which empirical results in terms of net safety effects are available.

(3) The application of the approach to available new technology that may have a bearing on road safety, where the input is provided by the developments taking place within the European 'PROMETHEUS' and 'DRIVE' programs, as well as within the American 'IVHS' program.

(4) The 'bottom-up' application of the approach, that is, the identification of what would be the most promising areas for developing technology from a safety point of view, given what knowledge we have about, e.g., behavioral adaptation and behavior-safety relations.

It is our intention to proceed along these lines, presenting results as they become available to the 'PRO-SAFE' Group within the PROMETHEUS program.

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REFERENCES

EVANS L. 1985, Human behavior feedback and traffic safety, Human Factors 27, 555-576

EVANS L.1987a, Belted and unbelted driver accident involvement rates compared, Journal of Safety Research 18, 57-64

EVANS L.1987b, Estimating fatality reductions from increased safety belt use. Risk Analysis 7, 49-57

EVANS L. & WASIELEWSKI P. 1983, Risky driving related to driver and vehicle characteristics. Accident Analysis & Prevention 15, 121-136

JANSSEN W.H. & TENKINK E. 1988, Considerations on speed selection and risk homeostasis in driving. Accident Analysis & Prevention 20, 137-142

KOORNSTRA M.J. 1990, Analyse van veiligheidseffecten van veranderingen in snelheden: een mathematisch-theoretische analyse, Institute of Road Safety Research SWOV, Leidschendam

NEUMANN L.1991, The contributions of PRO-GEN to the Common European Demonstrators. Contribution to Munich Workshop, October 1991

NILSSON G.1984, Speeds, accident rates and personal injury consequences for different road types. Linköping: VTI, Report No. 277

O'NEILL B. 1977, A decision-theory model of danger compensation. Accident Analysis & Prevention 9, 157-165

WILDE G.J.S. 1982, The theory of risk homeostasis: Implications for safety and health. Risk Analysis 2, 109-258

WILDE G.J.S. 1988, Risk homeostasis theory: Propositions, deductions and discussion of recent commentaries. Ergonomics 31, 441-468