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IMPROVING TRAFFIC SAFETY: CONCEPTUAL CONSIDERATIONS FOR SUCCESSFUL ACTION

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16. Abstract

In the early stages of motorization, it did not take rigorous scientific research to achieve major improvements in traffic safety. Instead, early traffic-safety countermeasures were often based exclusively on common sense. Since then, scientific research has gradually increased in importance as the basis for developing successful interventions. This shift was not made by choice but mostly by necessity: Many of the "easy" problems have already been addressed, and the remaining problems are generally too complex for an approach based on common sense. Fortunately, our understanding of the complexities involved in traffic safety has recently made major gains, and common sense can now be supplemented, to some degree, by valid technical analysis.

This report discusses major conceptual issues that should be considered in guiding the future development of effective, science-based traffic-safety countermeasures. After briefly discussing the issues, the report offers a list of implications for action.

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Contents

Introduction

In the early stages of motorization, it did not take rigorous scientific research to achieve major improvements in traffic safety. Instead, early traffic-safety countermeasures were often based exclusively on common sense (Sivak, 2002). Since then, scientific research has gradually increased in importance as the basis for developing successful interventions. This shift was not made by choice but mostly by necessity: Many of the “easy” problems have already been addressed, and the remaining problems are generally too complex for an approach based on common sense. Fortunately, our understanding of the complexities involved in traffic safety has recently made major gains, and common sense can now be supplemented, to some degree, by valid technical analysis. For recent comprehensive reviews of the current state of the art (or better, science), see Elvik and Vaa (2004), Evans (2004), and Shinar (2006).

This report will discuss major conceptual issues that should be considered in guiding the future development of effective, science-based traffic-safety countermeasures. After briefly discussing the issues, the report will offer a list of implications for action.

Conceptual considerations

Total harm

The starting point of our discussion is an approach to total harm proposed by Thulin and Nilsson (1994). In this approach, total harm is conceptualized as a product of exposure, risk, and consequences (see Figure 1).

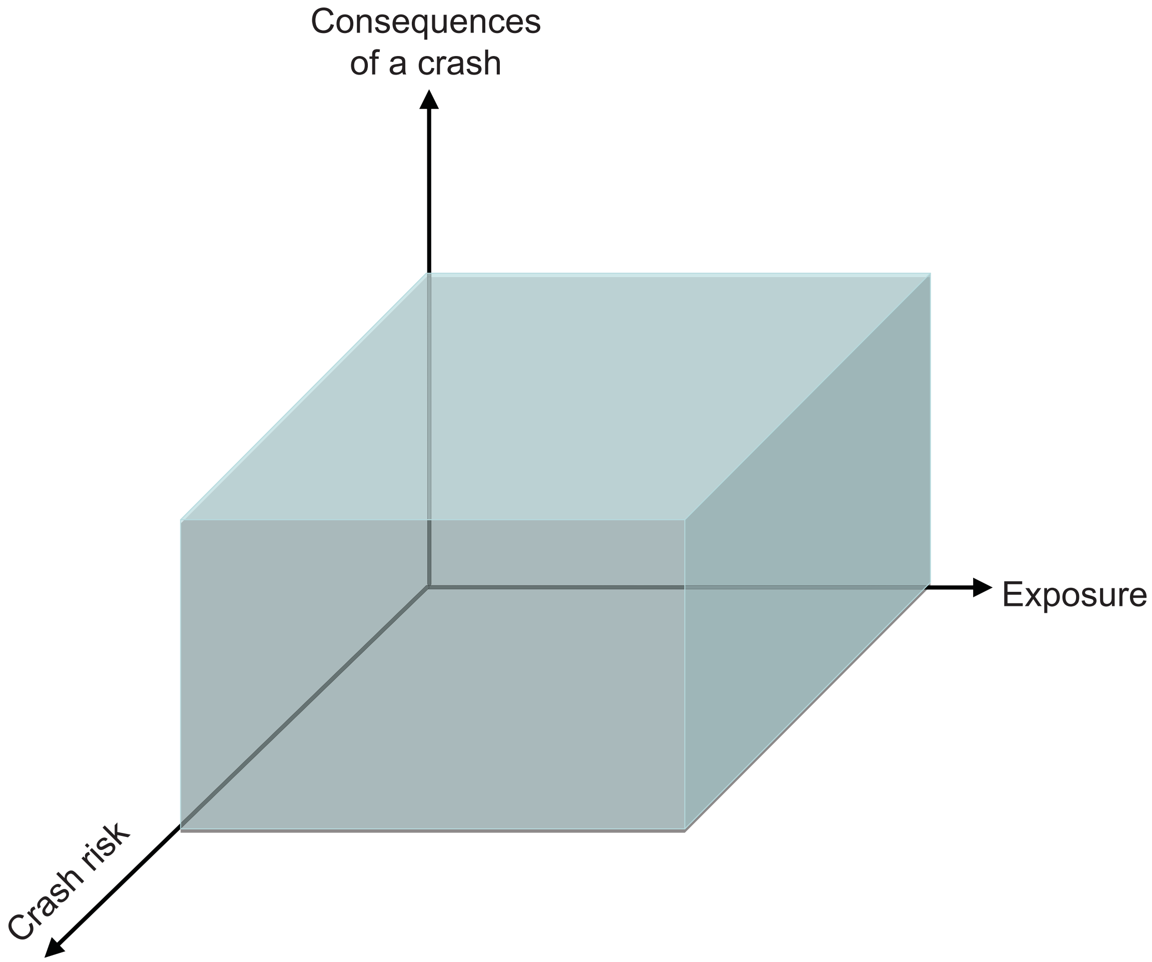

Figure 1. Total harm as the volume formed by a three-dimensional space of exposure, risk, and consequences. (Adapted from Thulin and Nilsson [1994].)

Exposure is the probability of a particular event (condition, situation) per distance traveled. Risk is the conditional probability of a crash, given the event in question. Consequence is the conditional probability of a fatality (or a particular level of injury), given a crash that was precipitated by the event in question. For each event, the values along the three dimensions (exposure, risk, and consequences) define a three-dimensional space. The volume of this space is the total harm for this particular event. (We recently used this general framework in addressing current and anticipated road safety issues in China [Zhang, Tsimhoni, Sivak, and Flannagan, 2008].)

There are several important implications of this approach. First, a high value of total harm can be a consequence of a high value along any of the three dimensions. This is illustrated in Figure 2 that shows annual mileage (exposure), likelihood of a crash per distance driven (risk), and likelihood of a fatality per crash (consequence) by driver age. Total harm for different age groups is carried primarily by different dimensions: risk for young drivers, exposure for middle-aged drivers, and consequence for older drivers.

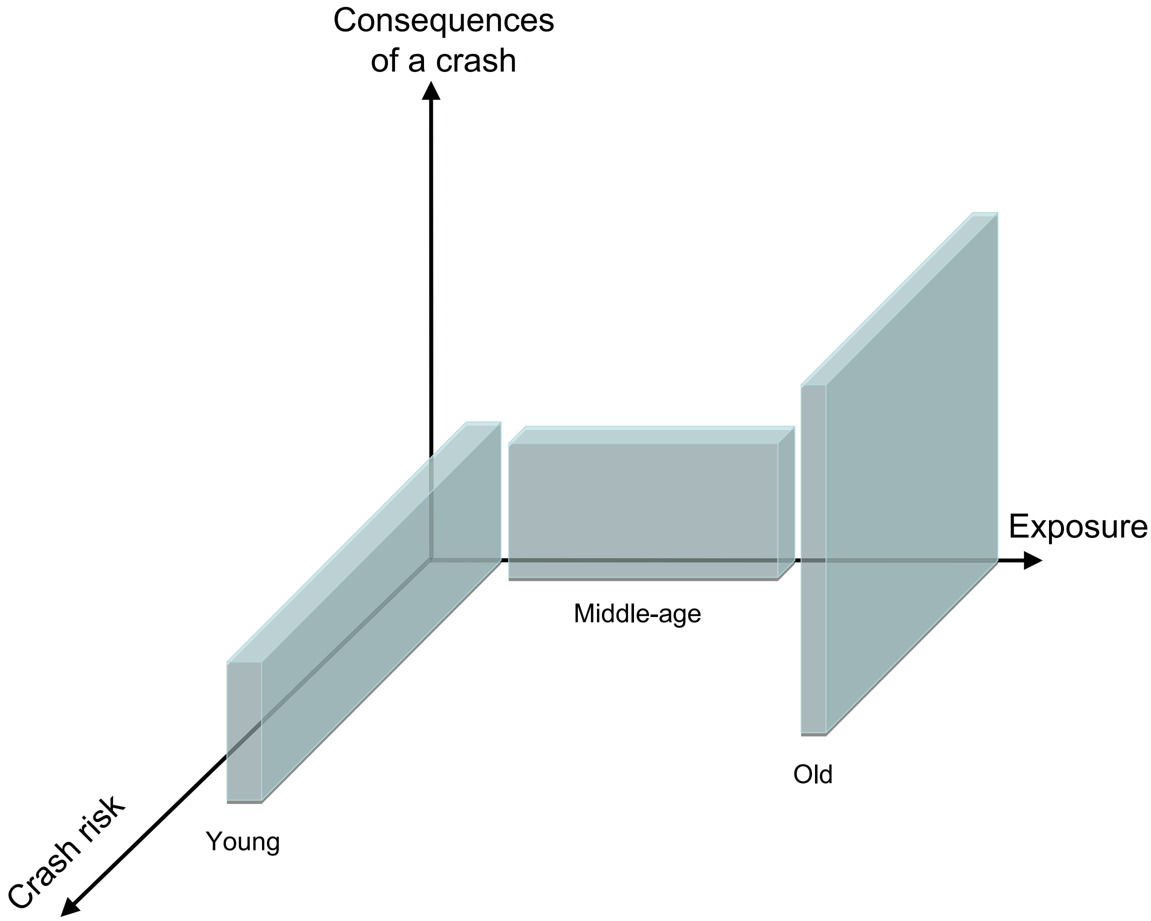

Figure 2. A schematic illustration of the total harm of road crashes (as a combination of exposure, risk, and consequences) by driver age in developed countries. Total harm for each age group is the volume of the corresponding three-dimensional space. (Adapted from Thulin and Nilsson [1994].)

The second important implication of this approach is that proportional changes in any of the three dimensions are equivalent in terms of the resultant changes in total harm. For example, a 25% decrease in exposure is functionally equivalent to a 25% decrease in risk or a 25% decrease in consequences.

The third implication, and a corollary to the previous one, is that effective interventions are *not* necessarily those that address the most dominant dimension of the problem. Let's again consider the age effect example in Figure 2. As indicated earlier, the total harm for young drivers is carried primarily by risk. Nevertheless, a 25% reduction in risk is no more effective than a 25% reduction in either exposure or consequences.

Amenability

When considering public health priorities in addressing preventable harm (deaths and injuries), knowledge concerning total harm needs to be supplemented with the facts about our current ability to change the situation. Therefore, amenability of total harm to intervention is of importance. Let's consider the following two scenarios (see Table 1). In Scenario 1, the total harm corresponds to 1,000 units (e.g., fatalities, serious injuries, etc.), and an available countermeasure can cut the harm by 50% (to 500 units). In Scenario 2, the total harm corresponds to 2,000 units, and another countermeasure can reduce the harm by 10% (to 1,800 units). In this example, addressing Scenario 1 would reduce the harm by more units, despite the fact that the baseline level of total harm is lower here than in Scenario 2. This is the case because addressing Scenario 1 would reduce total harm by 500 units, as opposed to 200 units if addressing Scenario 2.

Table 1
Baseline level of total harm, amenability, and net benefits.

Scenario	Baseline level of total harm (arbitrary units)	Effectiveness of a countermeasure (%)	Net benefits (arbitrary units)
1	1,000	50	500
2	2,000	10	200

Amenability of total harm could be due to the amenability of any of its three components: exposure, risk, or consequences (see Figure 3). Let us consider an example of total harm from crashes due to making unprotected left turns across traffic. The total harm here could be reduced by interventions along any of the three dimensions of the space. For example, exposure could be reduced by increasing the frequency of locations where left turns are not allowed or by installing more left-turn arrows. Risk could be lowered by installing collision-warning systems or by reducing the posted speed. Finally, consequence could be minimized by installing side-impact and curtain airbags, or by installing technology that would reduce the likelihood of a rollover after an initial impact.

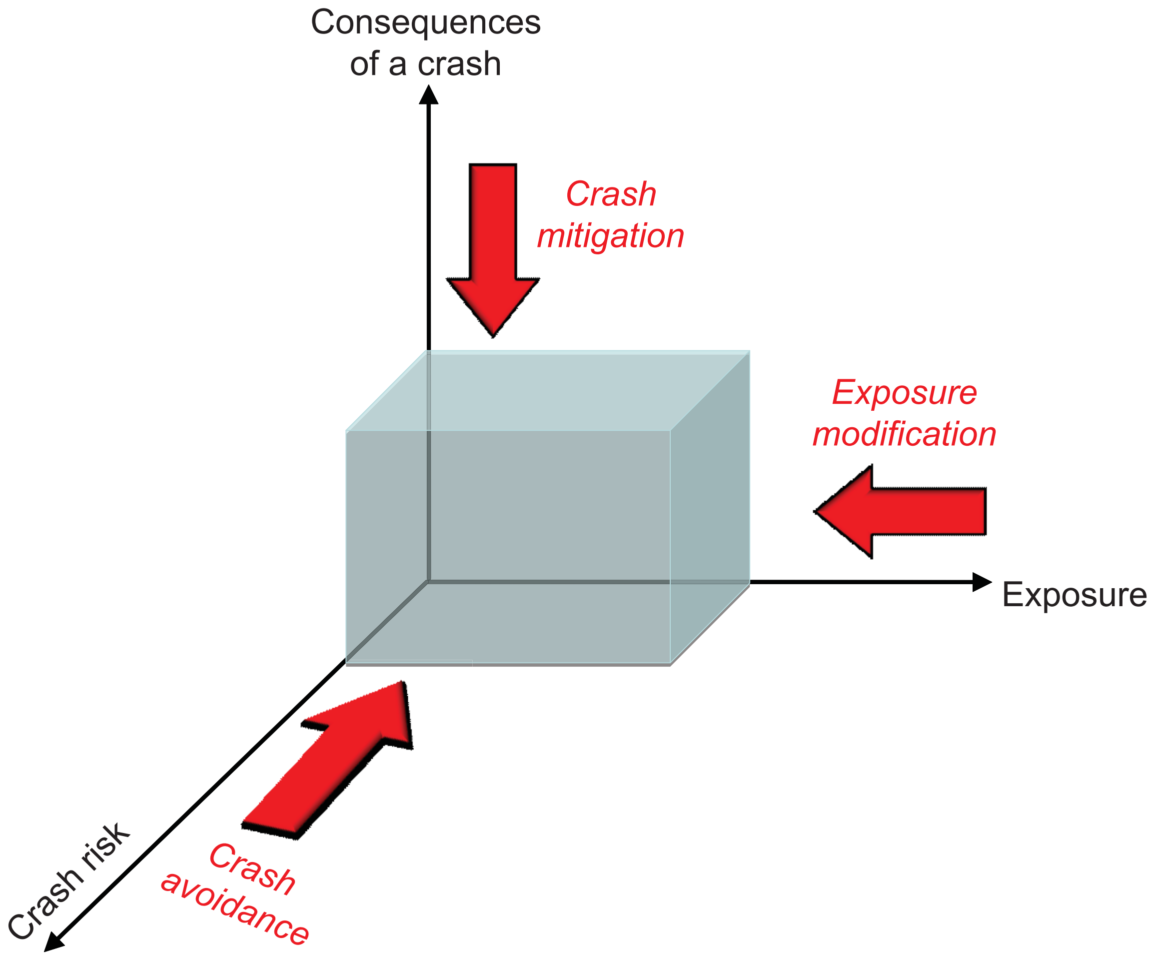

Figure 3. Amenability of total harm as a consequence of amenability of exposure, risk, or consequences.

Cost-benefit analysis

Each countermeasure has an associated cost that needs to be compared to the benefits gained. However, there are two broad classes of problems in doing such a cost-benefit analysis. The first class of complexities concerns the estimated costs: Some of the costs are in actual dollars (e.g., the cost of a device, such as an additional left-turn arrow), while other costs are in imputed dollars (e.g., of lost wages).

The second class of complexities relates to estimating the value of the benefits. Let's consider the valuation of life (e.g., Trawen, Maraste, and Persson, 2002; Viscusi and Aldy, 2003; Saelensminde, 2003). There are three types of sub-costs: direct (emergency and medical treatment, funeral, and damage to property), lost production, and pain/suffering (Saelensminde, 2003). Because the official valuations differ in what is included in the final figure, there is a large variation among countries in the valuation of life, even when adjusting for purchasing power of the currencies. For example, the purchasing-power-parity-adjusted value in the U.S. is $3,600,000, while in Portugal it is $56,000 (Saelensminde, 2003). Consequently, even if the estimated cost of a given countermeasure and its effectiveness were to be the same in these two countries, the countermeasure might turn out to be cost-beneficial in the U.S., but not in Portugal.

Future effectiveness of a given countermeasure

The effectiveness of many countermeasures depends on societal circumstances that may change with time, such as the age distribution of drivers, and the degree of intoxicated driving, driving without using safety belts, and speeding. Consequently, as such societal patterns change, so do the benefits of many countermeasures. Accurate predictions about changes in such societal patterns are thus prerequisites for estimating future benefits of many countermeasures. Research on modeling the relationships between the influence of societal patterns on the benefits of existing and planned countermeasures is ongoing (Flannagan and Flannagan, 2007).

Law of increasing returns

The effects of many interventions are more substantial on relatively unsafe drivers than on relatively safe drivers. This is the case because unsafe drivers tend to be unsafe in numerous aspects. For example, drivers who do not wear safety belts are also the drivers who are more likely to be involved in crashes and have more severe crashes (Evans, 2004). Thus, a given percentage change in safety belt use reduces the total fatalities more as the baseline level increases. This argument applies to other interventions such as the control of speeding and of driving while intoxicated. It follows that achieving success in terms of safety belt use, not driving while intoxicated, and speed control with the remaining drivers that currently still transgress is not a matter of diminishing returns, but just the opposite. Evans (2004) refers to this as the *law of increasing returns*.

Micro and macro adaptation

Because of behavioral adaptation, some countermeasures do not work as intended. An extreme version of behavioral adaptation—risk compensation or homeostasis— posits that drivers adjust their behavior to maintain a constant level of perceived risk (e.g., Adams, 1985; Wilde, 1989). For example, this theory would postulate that drivers reduce their speed when driving on ice in such a way that the resulting risk of being involved in a crash remains approximately the same as on dry pavement. Although there are serious reservations about this extreme version of behavioral adaptation, there is experimental evidence that drivers do adjust their behavior in response to perceived changes in risk. For example, drivers on ice chose higher speeds when equipped with studded tires compared to standard tires (Rumar, Berggrund, Jernberg, and Ytterbom, 1976). However, the adaptation was only partial: The increase in speed was not large enough to fully negate the benefits of increased friction with studded tires.

Clearly, if the driver is not aware of the countermeasure, even partial risk compensation is not possible. Consequently, everything being equal, countermeasures that are not obvious to traffic participants are preferred to those that are.

Risk compensation could be considered an example of micro adaptation. There is also a more subtle form of adaptation that involves macro adaptation. An example, involving modal shift, comes from research on driver licensing. Hakamies-Blomqvist, Johansson, and Lundberg (1996) compared crash involvement of older drivers in Sweden (with very liberal licensing laws of older drivers) and Finland (with relatively strict licensing). The results indicated that the age-related patterns of driver crashes were similar in the two countries. However, fatalities among pedestrians and bicyclists increased more sharply with age in Finland than in Sweden, suggesting a shift to more risky modes of transportation in the country with stricter licensing of older drivers.

Complex effects of countermeasures

Most countermeasures have not only some degree of the desired effect but also some degree of undesired effect. Examples include wider A, B, and C pillars (increased roof strength, decreased visibility out of the cabin), safety belts (increased protection in a crash, decreased mobility after a crash), higher mounting position of headlamps (increased visibility for the user, increased glare for oncoming and preceding traffic), and daytime running lights (increased visibility of the user, decreased relative visibility of non-users such as bicyclists).

Interactions of contributing factors

Road crashes are consequences of a complex interplay of driver, vehicular, and environmental factors. This broad statement applies even to those crashes that, on the face of it, were caused by a single, “simple” factor. Let’s consider the following example of a 4 a.m., run-off-the road crash that was classified by police as caused by a drowsy driver. Yes, if the driver in question did not drive past his or her “bedtime” (driver factor) the crash would not have occurred. However, the crash could have also been prevented by a drowsy-driver detection system (a vehicular factor), a road-departure warning system (a vehicular factor), or an effective rumble strip that alerts the driver if leaving the lane (environmental factor).

Interactions among countermeasures

Interactions are present among many countermeasures. Three different types of interactions are worth noting. The first type of interaction is the influence of one countermeasure on the opportunity of another countermeasure to reduce harm. Let's consider electronic stability control and curve-speed advisor systems. The potential benefits of curve-speed advisor systems are reduced by the presence of electronic stability control, because there are fewer instances where the advisor is potentially relevant.

The second type of interaction relates to the effect of one countermeasure on the desirable properties of another countermeasure. A good example here involves safety belts and airbags. In the U.S., the first generation of airbags was designed to save not only belted but also unbelted drivers. Consequently, they tended to be too aggressive for belted persons and led to the deaths of some smaller belted drivers and children (e.g., Ferguson and Schneider, in press).

The third type of interaction deals with the effectiveness of different countermeasures. Specifically, a countermeasure can have a negative or a positive influence on the effectiveness of another countermeasure. An example of a negative (detrimental) influence involves the effect of daytime running lights on the conspicuity of adjacent turn signals. On the other hand, an example of a positive (synergistic) influence is the effect of safety belts on the effectiveness of airbags (due to the control of the position of the occupant).

Implications for action

Based on the above discussion, here is a recommended checklist for action:

(1) Concentrate on total harm (as opposed to exposure, crash risk, or consequences).
(2) Deal with the most amenable of the three underlying dimensions of total harm (exposure, crash risk, or consequences).
(3) Consider the multiple sources of uncertainty in estimating costs and benefits.
(4) Be sensitive to current and expected societal trends.
(5) Pay attention to the law of increasing returns.
(6) Take into consideration micro and macro adaptation on the part of traffic participants.
(7) Consider the complex effects of most countermeasures.
(8) Be aware of interactions among contributing factors.
(9) Take advantage of interactions among countermeasures.

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