*The final publication is available in: Accident Analysis and Prevention. 127 (2019), 150-155.*
[10.1016/j.aap.2019.02.028](10.1016/j.aap.2019.02.028)

# How to trade safety against cost, time and other impacts of road safety measures

**Rune Elvik, Institute of Transport Economics, Gaustadalleen 21, 0349 Oslo, Norway (re@toi.no)**

## ABSTRACT

Public policy, including road safety policy, involves balancing competing values against each other. Several techniques of policy analysis, most prominently cost-benefit analysis, have been developed to help policy makers prioritize between different values. Valuation studies have not produced credible monetary values of life and limb. Cost-benefit analysis therefore cannot tell when the "right" balance has been struck between road safety and other objectives of transport policy. All formal tools of policy analysis are likely to reflect analyst values to a major extent, not the values of policy makers only. It is argued that policy choices and tradeoffs can be informed simply by providing factual information about impacts and not attempting to impose any value judgements. A widely applicable metric is to state impacts as changes in human longevity and health state.

Key words: road safety; cost-benefit analysis; tradeoffs; monetary valuation

## 1 INTRODUCTION

"One kind of optimism, or supposed optimism, argues that if we think hard enough, are rational enough, we can solve all our problems". This is the first sentence in Herbert Simon's book "Reason in human affairs" in which he discusses the concept of rationality and its role in, among other things, analyses of public policy (Simon 1983). The standard definition of individual rationality in modern economic theory is subjective utility maximization. To maximize subjective utility is simply to do what you think will bring you the greatest satisfaction of your preferences, or to put it shorter: to do what you like best. This notion of rationality is purely formal and has no empirical content. Moreover, it is strictly subjective, i.e. it refers only to what a person thinks and prefers, and not to some external standard of justified beliefs or socially acceptable preferences.

A somewhat different notion of rationality is needed for public policy analysis, e.g. analysis designed to help policy makers develop the most effective road safety policy. Policy decisions are rarely made by a single individual; preferences, i.e. the outcomes policy seeks to bring about, are usually complex, multiple and sometimes controversial; knowledge about the best means to accomplish policy objectives is usually incomplete, uncertain and possibly in dispute. Despite these complexities, welfare economics has proposed a prescriptive notion of rationality for public policy. The prescription is to perform a cost-benefit analysis designed to identify the policy that will maximize social welfare. Social welfare is maximized when the surplus of benefits over costs is as large as it can be, for a given set of policy objectives and policy instruments.

Will trying to realize a normative concept of rationality in this sense help improve road safety? To what extent can cost-benefit analysis provide guidance about how best to improve road safety? Can cost-benefit analysis balance considerations of safety, mobility, environmental quality and social equity in a way that adequately reflects what most individuals prefer? If not, how, if at all, can one then balance between conflicting policy objectives in a policy seeking to promote all the conflicting objectives? Are there other approaches to policy analysis than cost-benefit analysis that can help support road safety policy making? These are the main questions that will be discussed in this paper. Before discussing them, the necessity of making decisions and compromises will be briefly discussed.

## 2 DECISIONS AND COMPROMISES CANNOT BE AVOIDED

An objective of improving road safety is likely to have virtually unanimous support. Surely, if death and injury on the roads can be prevented, we ought to do so. But how drastic action should we take? Society needs transport. The options of prohibiting it or setting a speed limit close to zero are ruled out. If it is accepted that society needs a functioning transport system, which is as safe as possible, policy is made in the realm of trading off conflicting objectives and making compromises between them.

Some ideal conceptions of road safety, for example Vision Zero or the Dutch concept of Sustainable Safety (World Health Organization 2004A, International Transport Forum 2008) have been formulated in a way that gives improving safety an unconditional first priority. In this paper, long-term ideals for safety like Vision

Zero or Sustainable Safety are viewed as inspirational ideas and visionary targets, not as tools for policy analysis. They will therefore not be discussed further.

Compromises between objectives need not be made in economic terms. Yet, a form of thinking of an economic kind – which means recognizing the fact that resources are limited and can be put to very many alternative uses – is simply inevitable, given the following basic facts (Elvik 2012):

1. A limited amount of resources is at our disposal for the prevention of accidents or injuries.
2. Human needs and value systems are complex and multi-dimensional. Safety is certainly one of the more basic human needs, but it is not the only one. No society would ever be able to, or choose to, spend more than a rather small share of disposable resources on the prevention of accidents or injuries.
3. How much to spend on the prevention of accidents or injuries will depend, and ought to depend, on how important people think this good is, compared to all other goods they would like to see produced.

If these observations are accepted as a fair description of the choices we are facing, then a reasoning that tries to balance costs and benefits, although not necessarily formalised, is simply inevitable. It does not follow that trade-offs must be made in monetary terms or that everything can be meaningfully converted to monetary terms. Still, given the inevitability of making choices that involve balancing and trading off, adopting cost-benefit analysis to support these choices sounds attractive.

## 3 COST-BENEFIT ANALYSIS TO SUPPORT ROAD SAFETY POLICY

The main ideas of cost-benefit analysis are very simple. The first step is to identify all policy objectives to be included in the analysis. In transport policy, including road safety policy, the policy objectives typically include improving road safety, reducing congestion, providing shorter travel time, and reducing adverse environmental impacts of transport (global warming, local pollution, traffic noise). The second step is to make all policy objectives comparable by converting them to a common metric. Money is almost always chosen as the common metric. When all policy objectives have been converted to monetary terms, the benefits of specific programs or policy instruments can be compared to their costs. The combination of programs that gives the largest surplus of benefits can then be identified.

Underlying these simple ideas are a set of more basic principles that are controversial and restrict the types of issues that are suitable for cost-benefit analysis (Elvik 2001). Three important principles are commensurability, valuation based on willingness-to-pay, and potential Pareto improvement. Commensurability means that everything can be compared; that it is always possible to compensate for less of one good thing by providing more of another good thing. Some goods are incommensurable. You are not allowed to sell your right to vote in public elections. Likewise, basic human rights like freedom of speech, freedom of movement or the right to form organizations are not subject to economic tradeoffs.

In cost-benefit analysis, something has value if somebody is willing to pay for it; willing to buy it, so to speak. Demand, in the economic sense of the term, is the only source of value. Not all values are constituted this way. Watching a beautiful sunset has value, although most people would find the idea of restricting the right to view it to those who paid for it preposterous. Beautiful landscapes have a value by their mere existence, not just because you can exploit them for an economic gain in terms of farming, hunting, or mining.

Finally, the objective of cost-benefit analysis to maximize efficiency. Efficiency is a technical term in economics. A policy is efficient when those who gain from it can compensate those who lose from it and still have a net gain. This principle is usually referred to at the potential Pareto principle. It was proposed because public policy rarely produces a strict Pareto improvement, which means that it makes at least one person better off without making anyone worse off. The requirement of a potential Pareto improvement is generally regarded as satisfied when benefits (in monetary terms) exceed costs (in monetary terms).

When one of the policy objectives is to reduce death and injury, it is necessary to assign a monetary value to life and limb. Doing so is controversial. Some reject it as ethically wrong or meaningless (Broome 1978, Tingvall 1997, Ackerman and Heinzerling 2004, Hansson 2007). Others (Hauer 1994, 2011, Elvik 2018) argue that research on the monetary valuation of life and limb has failed to produce credible estimates of value. Published values vary enormously and it is challenging, perhaps impossible, to select a single best estimate from the very diverse values found in the literature.

The enormous diversity in estimates of the value of preventing a fatality casts doubt on the validity of the assumptions made in obtaining these values. All methods designed to elicit a monetary valuation of a good that does not have a market price assume that the valuation reflects stable underlying preferences satisfying a few elementary properties like asymmetry (one cannot both prefer A to B and B to A) and transitivity (if A is preferred to B and B to C, A must be preferred to C). A huge number of experiments have found that preferences often violate these basic properties; for extensive reviews, see e.g. Connolly et al. (2000), Gilovich et al. (2002), and Kahneman and Tversky (2000). Thus, one may doubt whether the assumption of well-ordered preferences made in valuation studies is true. If valuations do not reflect well-ordered preferences, their use in cost-benefit analysis will not produce a policy maximizing welfare.

It is challenging to extract a single best estimate of the value of preventing a fatality, even from a single study. Elvik (2017A) shows that extracting the best estimate from a single study can be done in at least three ways, all of which are defensible, but give different estimates. Thus, selecting a specific value from a specific study involves a large element of arbitrariness. Valuation studies must therefore be rejected because they have only produced widely divergent values that do not seem to reflect any stable underlying preferences.

This conclusion may strike readers as too hasty and categorical. Surely, it would be wrong to think that methodological innovations have come to an end and rule out that any future study would produce meaningful estimates. It is true that new guidelines for valuation studies are continually developed, see Johnston et al. (2017) for a recent example. The guidelines of Johnston et al. do not, however, address the major problems encountered in the valuation of life and limb and do not refer to a single valuation study dealing with the value of human life. Apparently, these guidelines are intended for the valuation of other topics.

It can be argued that cost-benefit analysis is possible and makes sense, despite the diversity in estimates of the value of preventing a fatality. Asplund and Eliasson (2016) argue that the results of cost-benefit analyses are surprisingly insensitive to uncertainty in the monetary valuations of impacts. This may certainly be correct as far as determining priority between projects within a given budget is concerned. Suppose the five projects with the largest net benefits in a program have net benefits (benefits minus costs) of, say, 100, 80, 60, 50 and 40 million NOK (1 NOK = 0.118 US Dollars in February 2019) according to a "high" valuation of benefits. For simplicity, assume each project costs the same, 20 million NOK, for a total of 100 million NOK. If all valuations of benefits are cut by 50 %, the net benefits become 40, 30, 20, 15 and 10. They all remain positive and the order of priority between the projects according to their net benefits is unaltered. From that point of view, changing the valuations makes no difference.

Valuations can, however, make a large difference with respect to the size of the budget containing measures whose benefits are greater than the cost. Elvik (2014) studied how the optimal number of killed road users in Norway depends on the valuation of preventing a traffic fatality. The optimal number of road accident fatalities is the number expected to occur when the marginal benefits of a road safety program equal its marginal costs. The initial annual number of traffic fatalities was 236. Applying a valuation of preventing a fatality of 15 million NOK, the optimal number was 157 and the size of the annual safety budget needed to reduce the number of fatalities from 236 to 157 about 2,000 million NOK. When valuing the prevention of a fatality at 30 million NOK, the optimal number of fatalities was estimated as 127 per annum, and the optimal safety budget close to 5,000 million NOK. Finally, applying a valuation of 60 million NOK per fatality prevented, the optimal annual number became 103 and the optimal size of the annual safety budget about 10,000 million NOK. The valuation of preventing a fatality thus makes a big difference with respect to how much government ought to spend on road safety according to cost-benefit analysis and how far down this will bring the number of fatalities. Given the huge uncertainty in the monetary values, it is not at all clear what the best answer is to the question: How much can we justify spending on road safety programs from a welfare-economic point of view?

This means that cost-benefit analysis cannot answer the main questions it was designed to answer: What is the best balance between road safety and other policy objectives? How much ought to be spent on road safety programs? The answers to these questions will be very different depending on the valuation chosen and choosing a single value even from a single study has a large element of arbitrariness. Can other tools for policy analysis give more certain answers than cost-benefit analysis?

## 4 OTHER APPROACHES TO POLICY ANALYSIS

One well-developed tool for policy analysis not requiring a monetary valuation of all impacts of a policy is multicriteria analysis. Like cost-benefit analysis, it sets out to identify all relevant impacts of a policy. These impacts are referred to as criteria, i.e. considerations that are relevant when making decisions.

Wiethoff et al. (2012) applied multicriteria analysis to decisions involving choice between infrastructure improvements and advanced driver support systems to reduce accidents. A large number of road safety measures were considered. A distinction was made between three groups of stakeholders: drivers, public policy makers and car manufacturers. For each stakeholder, criteria relevant to the choice between road safety measures were proposed. For example, criteria proposed for public policy makers included road network efficiency, overall safety, socio-political acceptance, public expenditures and environmental effects. The list of criteria does not need to be limited to criteria that can be quantified. It must, however, be possible to assess the importance of a criterion. One method for doing so, is the analytic hierarchy process. Pairs of criteria are then compared and rated for importance. If equally important, the value of 1 is assigned to them. If one criterion is more important than the other, it is scored from 3 up to 9 depending on how much more important it is.

The analytic hierarchy process originated in mathematical models of human judgement developed in mathematical psychology. Although mathematically advanced, the technique is more flexible than cost-benefit analysis by allowing for the inclusion of criteria of a non-economic nature and by allowing for fuzzy judgements, i.e. comparisons in which there is doubt about which is the more important criterion or the better choice. Until now, however, very few applications of multicriteria analysis relying on the analytic hierarchy process or related techniques can be found in road safety.

Macharis and Bernardini (2015) reviewed the use of multicriteria analysis in transport projects. They found that it tended to be used to evaluate major investments. Road safety measures is not mentioned on their list of applications. Logically and mathematically, multicriteria analysis resembles linear programming, a technique for finding optimal solutions to problems where any solution must satisfy one or more constraints. An attraction of linear programming is that it allows a budget to be defined as a binding constraint, thus deflecting the objection proponents of cost-benefit analysis often make against other formal techniques applied in policy analysis, namely that these techniques cannot tell when something is too expensive.

Common to cost-benefit analysis and multicriteria analysis is that either the analyst, or the analyst together with policy makers or a sample of the population, must specify and assess the importance of a set of criteria or impacts of a policy. Given the complexity of many choices and the fact that preferences are often vague and sensitive to clues provided by the analyst, all formal techniques of policy analysis relying on input from the public or policy makers, solicited by analysts, entails the risk that the analyst has decisive influence on the results of analysis. Policy analyses may thus principally reflect the perspective of analysts and not of the public or policy makers. Does analysis impose or reflect values? That is a major issue for all formal techniques of policy analysis, to which the answer is not obvious.

Is it possible to analyze impacts of public policy, especially road safety policy, in terms of comparable and objective indicators of impacts that do not require elicitation of preferences, but nevertheless permit a comparison of costs and benefits in the same metric? Yes, such analyses are possible and an instructive example of how to do them is given by Furberg et al. (2018).

## 5 THE HEALTH LIFE-CYCLE APPROACH

Furberg et al. (2018) would like to know – in the spirit of cost-benefit analysis – whether the benefits of using studded tires exceed the costs. They state all impacts of studded tires as health impacts, i.e. as changes in human longevity and health state. To measure health state, they apply Disability Adjusted Life Years, abbreviated DALYs. A DALY takes the value of 0 if there is no health impairment (no disability or loss of function) and the value of 1 in case of death. The closer a value is to 1, the greater is the disability associated with a certain health impairment.

There are many estimates of DALYs associated with specific diseases or injuries in the literature. These estimates are not always the same, but vary much less than estimates of the monetary value of preventing a fatality. For an overview of DALYs, and the functional impairment associated with various health states, see e.g. Miller (1993), World Health Organization (2004B) and Haagsma et al. (2012). It should be noted that although minor conditions can be assigned quite different DALY-values, the DALYs associated with major and life-long impairments tend to be scored at nearly the same value in the currently most widely used catalogues of DALY-values. Thus, fracture of the wrist is given a disability weight of 0.020 by WHO (2004B) and 0.069 by Haagsma et al. (2012). A disability weight of 0.02 corresponds to 0.02 DALYs. By contrast, a spinal cord injury is given a disability weight of 0.725 by

WHO, 0.676 by Haagsma et al. and 0.680 according to the Functional Capacity Index (Miller 1993).

Studded tires are intended as a road safety measure; yet it has other impacts as well. Furberg et al. (2018) include the following impacts in their analysis: (1) Road safety impacts; (2) Particle emissions from the road surface (studs tear up small particles from the road); (3) Emissions during the production of studs; (4) Occupational accidents during the production of studs, and (5) Conflict casualties from civil war funded by income from cobalt mining. The latter three items have not been included in any cost-benefit analyses of studded tires.

Furberg et al. (2018) state the results as changes in DALYs per car per year using studded tires (assuming all four tires are studded). Since accidents are rare events, the changes in DALYs per car per year are very low numbers, in the order of 1 per 10,000 to 1 per 1,000,000. To make their results easier to understand, their estimates have been rescaled by multiplying them by 100,000,000. The results are reproduced in Figure 1.

***Figure 1 about here***

To indicate uncertainty, Furberg et al. (2018) made low and high estimates. These are connected by the vertical lines in Figure 1. Gains in DALYs are shown as positive numbers (benefits), losses in DALYs are shown as negative numbers (costs). Several observations can be made. First, the amount of uncertainty is shown by the length of the vertical lines; it is immediately apparent that some impacts are more uncertain than others. Second, the contribution of an impact to the overall net balance of positive and negative impacts can be readily determined. Third, only factual information is given; no attempt is made to elicit values or preferences or opinions regarding the relative importance of the impacts. Fourth, the user of the information can decide for himself or herself what impacts should count. As noted above, only safety impacts and particle emissions have been included in traditional cost-benefit analyses. Including impacts arising from the production of studs should not be controversial, but including civil war victims in Congo, where most of the cobalt used in studs is mined, may strike some as a bit farfetched. However, as can be seen, that item contributes very little to the sum of impacts. The impacts that can be influenced by policy makers who have the authority to regulate the use of studded tires in a specific country are safety and emissions. These are the most relevant impacts for policy makers; the other impacts occur outside the system they can influence.

Overall impacts are obtained by summing the five impacts. Furberg et al. (2018) appears to have made an error in summing effects. To show the full span of outcomes, the upper estimate should be the sum of all upper estimates, i.e. 25,000 + (-14,000) + (-2,400) + (-1,800) + (-72). This comes to 6,728, showing that, in theory it cannot be ruled out that the safety benefits outweigh all the other impacts. Summing the lower estimates gives a value of -69,940. The downside looms larger than the upside. A risk-averse decision maker would conclude that there is more to lose than to gain by using studded tires.

Similar analyses can be made of other road safety measures. Human longevity and health state is the natural yardstick for measuring impacts. Analyses show changes in DALYs. No value judgements are made by analysts, except perhaps by choosing

DALYs as estimator of impacts; that choice can be interpreted as implying that more DALYs is a good thing. That should hardly be controversial. It is difficult to imagine how reducing DALYs (i.e. shortening lifespan or reducing health state) could be a legitimate objective of public policy.

The impacts of changes in speed limits can be stated as changes in human longevity and health state. Based on Elvik (2017B), Figure 2 shows changes in DALYs associated with lowering the speed limit from 80 to 70 km/h on high-risk roads in Norway. Depending on how much speed is reduced (lower estimate -1.5 km/h; upper estimate -6.5 km/h), there will be changes in fatalities and injuries and in travel time. These changes are functionally related through the change in speed and are therefore proportional but have opposite signs (the larger the speed reduction, the larger gain in safety, and the larger the addition to travel time). Based on statistics from Statens vegvesen (2018), occupational risks to road workers installing speed limit signs were included but turned out to contribute very little to overall impacts. As the roads are located in rural areas, any environmental impacts were judged to be negligible.

*Figure 2 about here*

It is seen that lowering the speed limit from 80 to 70 km/h is associated with a net gain in DALYs. In other words: although you, as a driver, may spend a little more time on the road, your overall supply of high-quality time increases, as your chances of survival and of avoiding serious injury increase. If similar analyses were made of many road safety measures, it would be possible to rank the measures according to the gain in DALYs produced by them. Thus, simply providing this factual information can support priority setting.

## 6 DISCUSSION

How can an effective road safety policy be implemented without giving up an efficient transport system? This is an important question facing policy makers all over the world. To help them find a good answer to the question, formal tools of policy analysis have been developed. Possibly the most refined of these is cost-benefit analysis. It promises optimal solutions, i.e. solutions that are the best possible given all relevant policy objectives and the importance given to these objectives.

In practice, cost-benefit analysis cannot deliver what it promises. There are many reasons for that. One important reason is that the monetary valuation of human life and limb is much too imprecise and uncertain to allow for anything but the roughest estimates of the benefits of improving road safety. One cannot, with any confidence, tell whether “too much” or “too little” is being spent on road safety. Thus, cost-benefit analysis cannot perform the function it is intended to perform, which is to help get the right balance between safety and other objectives, like travel time or environmental protection.

At a more fundamental level, cost-benefit analysis relies on assumptions that are controversial and unlikely to be true. It assumes that the marginal value of money is the same for a rich person as for a poor person. It assumes that transfers between gainers and losers, to ensure that everybody gets a net benefit, are costless. It assumes that willingness-to-pay expresses stable values. It approaches public policy problems that do not have market solutions by creating imaginary and hypothetical markets where individuals "purchase" goods that are not for sale in the real world, like human life and limb. It is small wonder that cost-benefit analysis is controversial.

Other formal tools for policy analysis, e.g. multicriteria analysis, have so far found less application to road safety policy than cost-benefit analysis. Multicriteria analysis shares with cost-benefit analysis the requirement that individuals, government agencies or politicians are able and willing to articulate values and tradeoffs between values. Once the relevant values have been articulated, finding the best mix of policy instruments to realize them is a matter of calculation only. This approach assumes a certain level of agreement on values. If there is disagreement about values, such disagreement cannot be resolved by calculation. It must be resolved by discussion or negotiation, if it can be resolved at all.

A case can therefore be made for policy analyses that present factual information only and do not attempt to make value judgements. Some may object that a clear distinction between facts and values cannot be made (Putnam 2002). It can be argued that the choice of which facts to present is based on values. Be that as it may, presenting the impacts of road safety policy in terms of changes in public health, stated, for example as Disability Adjusted Life Years (DALYs), should be less controversial than presenting them as monetary amounts of dubious origin. A graphical presentation of impacts can easily visualize uncertainty. It is difficult to see that this could be as controversial as cost-benefit analysis. Surely, few would argue that it is wrong to increase the amount of DALYs in society, i.e. to increase the length and health-related quality of human life. This is what road safety is all about.

Can purely factual information on changes in DALYs inform tradeoffs? It can indeed. In one of the examples given, the negative impacts of studded tires appeared to be greater than the positive impacts, suggesting that studded tires are not a very good safety measure when all impacts of it are taken into account (in the same metric). To accept this conclusion, the only value judgement one needs to make is that increasing DALYs is better than reducing them.

## 8 CONCLUSIONS

The following main conclusions can be drawn from the discussion in this paper:

1. The aim of formal tools for policy analysis is to provide an informed basis for making tradeoffs between multiple policy objectives. Cost-benefit analysis makes all policy objectives comparable by converting them to monetary terms.
2. Research has not produced credible monetary values for human life and limb. The values found in the literature are extremely diverse and there is no obviously correct way of extracting the best estimate even from a single study, let alone the full body of studies found in the literature.
3. Neither cost-benefit analysis nor other formal techniques of policy analysis can be regarded as neutral in the sense that the results of analysis reflect the value judgements of respondents only. On the contrary, analysts exert considerable influence on the results of the analyses.
4. It is possible to inform tradeoffs between policy objectives by providing factual information only, without attempting to formalize value judgements

in monetary terms. Stating all impacts of road safety measures as changes in human longevity and health provides factual information that can inform choices.

## ACKNOWLEDGEMENTS

This study was partly funded by the Concept research program at the Norwegian University of Science and Technology, partly it was performed without funding.

## REFERENCES

Ackerman, F., Heinzerling, L. 2004. Priceless: On knowing the price of everything and the value of nothing. New York, W. W. Norton & Company.

Asplund, D., Eliasson J. 2016. Does uncertainty make cost-benefit analysis pointless? Transportation Research Part A, 92, 195-205.

Broome, J. 1978. Trying to value a life. Journal of Public Economics, 9, 91-100.

Connolly, T., Arkes, H. R., Hammond, K. R. (Eds). 2000. Judgment and Decision Making. An interdisciplinary reader. Cambridge, Cambridge University Press.

Elvik, R. 2001. Cost-benefit analysis of road safety measures: applicability and controversies. Accident Analysis and Prevention, 33, 9-17.

Elvik, R. 2012. Cost-benefit analysis. Text written for European Road Safety Observatory (ERSO) website.

Elvik, R. 2017A. Does valuation research provide a credible basis for cost-benefit analysis of safety measures? International Journal of Business Continuity and Risk Management, 7, 192-203.

Elvik, R. 2017B. Miniscenario: Fartsgrensepolitikk. Virkninger på trafikksikkerhet av ulike fartsgrenser. Rapport 1589. Oslo, Transportøkonomisk institutt.

Elvik, R. 2018. The value of life. The rise and fall of a scientific research programme. Newcastle-upon-Tyne, Cambridge Scholars Publishing.

Furberg, A., Arvidsson, R., Molander, S. 2018. Live and let die? Life cycle human health impacts from the use of tire studs. International Journal of Environmental Research and Public Health, 15, 1774. doi:10.3390/ijerph15081774

Gilovich, T., Griffin, D., Kahneman, D. (Eds). 2002. Heuristics and biases. The psychology of intuitive judgment. Cambridge, Cambridge University Press.

Haagsma, J. A., Polinder, S., Lyons. R. A., Lund, J., Ditsuwan, V., Prinsloo, M., Veerman, J. L., Beeck, E. F. van. 2012. Improved and standardized method for assessing years lived with disability after injury. Bulletin of the World Health Organization, 90, 513-521.

Hansson, S. O. 2007. Risk and ethics. Three approaches. In Lewens, T. (Ed): Risk. Philosophical Perspectives, 21-35. London, Routledge.

Hauer, E. 1994. Can one estimate the value of life or is it better to be dead than stuck in traffic? Transportation Research Part A, 28, 109-118.

Hauer, E. 2011. Computing what the public wants: some issues in road safety cost-benefit analysis. Accident Analysis and Prevention, 43, 151-164.

International Transport Forum. 2008. Towards zero. Ambitious road safety targets and the safe system approach. Paris, OECD publications.

Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., Hanemann, W. M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., Vossler, C. A. 2017. Contemporary guidance for stated preference studies. Journal of the Association of Environmental and Resource Economists, 4, 319-405.

Kahneman, D., Tversky, A. (Eds). 2000. Choices, values and frames. Cambridge, Cambridge University Press.

Macharis, K., Bernardini, A. 2015. Reviewing the use of Multi-Criteria Decision Analysis for the evaluation of transport projects: Time for a multi-actor approach. Transport Policy, 37, 177-186.

Miller, T. 1993. Costs and functional consequences of U.S. roadway crashes. Accident Analysis and Prevention, 25, 593-607.

Putnam, H. 2002. The collapse of the fact/value dichotomy and other essays. Cambridge, Mass. Harvard University Press.

Simon, H. A. 1983. Reason in human affairs. Oxford, Basil Blackwell.

Statens vegvesen. 2018. Årsrapport 2017. Oslo, Statens vegvesen, Vegdirektoratet.

Tingvall, C. 1997. The Zero Vision. A Road Transport System Free from Serious Health Losses. In Holst, H. von, Nygren, Å. and Thord, R. (Eds): Transportation, Traffic Safety and Health, 37-57. Berlin, Springer Verlag.

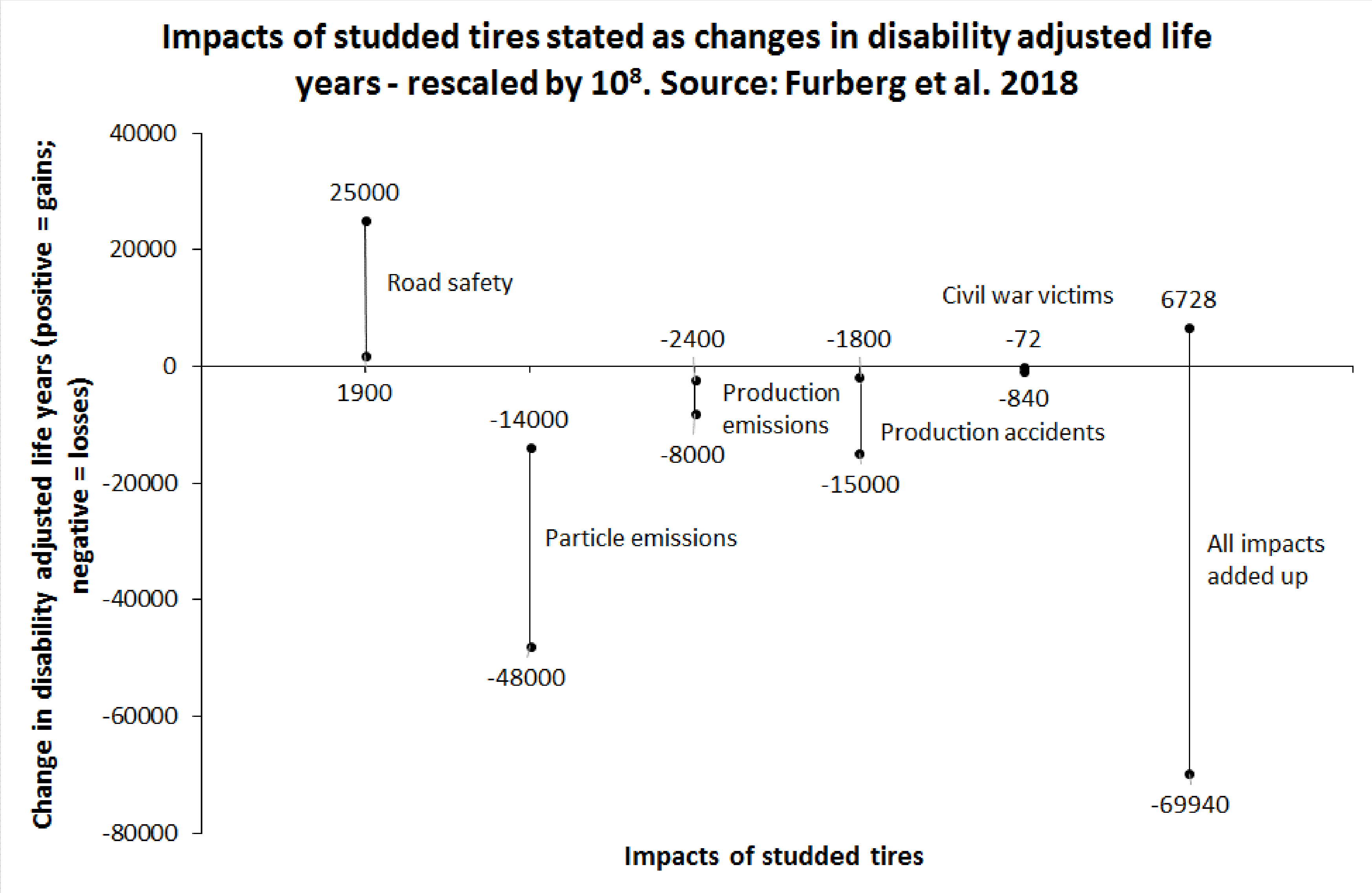
Wiethoff, M., Brookhuis, K., de Waard, D., Marchau, V., Walta, L., Wenzel, G., de Brucker, K., Macharis, K. 2012. A methodology for improving road safety by novel infrastructural and in-vehicle technology combinations. European Transport Research Review, 4, 67-77.

World Health Organization. 2004A.  World report on road traffic injury prevention. Geneva, World Health Organization.

World Health Organization. 2004B. Global Burden of Disease 2004 update: disability weights for diseases and conditions. Geneva, World Health Organization.

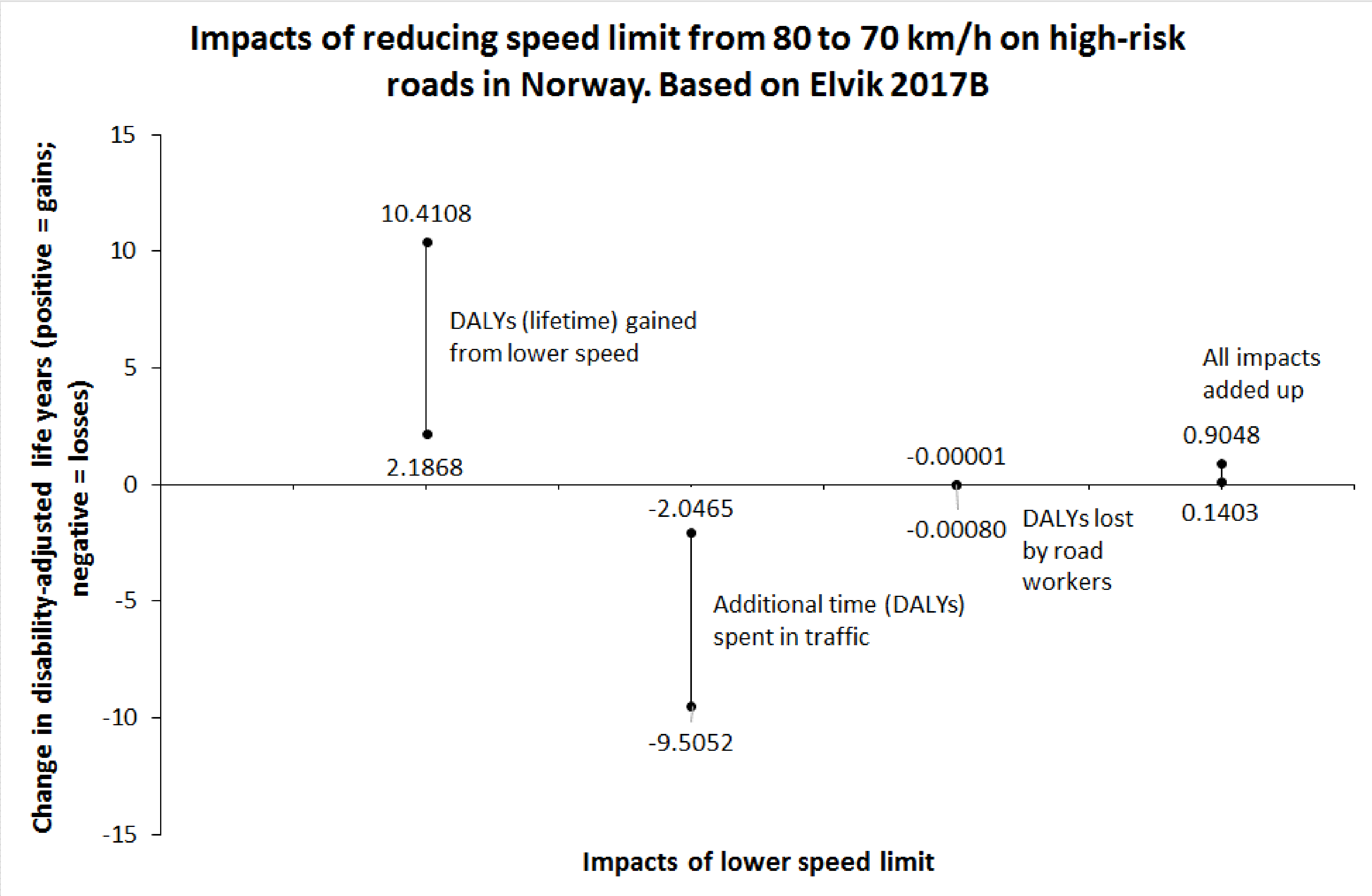
**LIST OF FIGURES AND TABLES**

Figure 1:



Impacts of studded tires stated as changes in disability adjusted life years - rescaled by 10^8. Source: Furberg et al. 2018
Change in disability adjusted life years (positive = gains; negative = losses)
40000
20000
0
-20000
-40000
-60000
-80000
25000
Road safety
1900
-14000
Particle emissions
-48000
-2400
Production emissions
-8000
-1800
-15000
Production accidents
Civil war victims
-72
-840
6728
All impacts added up
-69940
Impacts of studded tires

Figure 2:


Impacts of reducing speed limit from 80 to 70 km/h on high-risk roads in Norway. Based on Elvik 2017B
Change in disability-adjusted life years (positive = gains; negative = losses)
15
10
5
0
-5
-10
-15
10.4108
2.1868
DALYs (lifetime) gained from lower speed
-2.0465
-9.5052
Additional time (DALYs) spent in traffic
-0.00001
-0.00080
DALYs lost by road workers
All impacts added up
0.9048
0.1403
Impacts of lower speed limit