SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

# SPSD II

# ECONOMIC ANALYSIS OF TRAFFIC SAFETY: THEORY AND APPLICATIONS

S. PROOST, G. DE GEEST

GENERAL ISSUES

AGRO-FOOD

ENERGY

PART 1

SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS — TRANSPORT

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SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

**Part 1:**
**Sustainable production and consumption patterns**

FINAL REPORT

# Economic Analysis of Traffic Safety: Theory and Applications

**CP/38**


Prof. Stef Proost
Center for Economic Studies
K.U.Leuven

Prof. Gerrit De Geest

Centre for Advanced Studies in Law and Economics
Ghent University


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Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person:
Mr Marc Van Heuckelom
Secretariat: +32 (0)2 238 37 61

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# Chapter I: Introduction

# 1. Introduction to the project

## *1.1.* Context and Summary

Traffic accidents cause substantial costs to society and there is a widely accepted belief that these costs are excessive and should be reduced. Nevertheless, the means available to reduce the accident costs are limited and so are the available resources. The project aims to contribute to the solution of this choice problem by a theoretical and empirical analysis of various traffic safety measures. For this it uses an interdisciplinary approach, with contributions from both law and economics.

## *1.2.* Objectives

The project analyses the potential and limitations of various transport safety measures and investigates to what extent they are complementary. The focus lies on regulatory instruments, liability rules, economic instruments and infrastructure measures. An interdisciplinary approach is used: we aim to integrate insights from economics and law and economics.

- In economics the focus lies on the determination of accident costs and on the evaluation of pricing, infrastructure measures and technical regulation. The legal rules are taken as given.
- The law and economic approach has two goals: (1) predicting the rational responses of individuals to changes in legal rules: (2) designing legal rules in such a way that certain goals may be attained in a cost-effective way. Thus, the law and economics approach will be focused on the analysis of the effects of different legal rules on the behaviour of people in situations that may lead to accidents. Once a predictive model is clarified, the desirability of changes in the legal rules can be appreciated in relation to the changes that we want to attain in people’s behaviour.

Both approaches can bring new insights to the problem of how to reduce the overall costs of traffic accidents in the most efficient way.

The project consists of three steps:

- In a first step we make an overview of existing and potential measures which are aimed at improving traffic safety.
- A second step considers the problem from a theoretical angle. We base ourselves on theoretical models from transport economics and law and economics.

- In a third step we apply the theoretical insights to Belgium. We calculate the welfare effects of concrete policy packages.

The goal of the project is to provide policy guidance, based on theoretical and empirical analysis, to improve traffic safety in Belgium.

# 2. Overview of results

## *2.1.* Description of tasks

The project covers five tasks: (A) coordination and valorisation, (B) overview and selection of measures aimed at improving traffic safety, (C) theoretical analysis, (D) evaluation of measures to improve traffic safety: applications, (E) policy conclusions.

In this section we give a broad outline of what has happened for the different tasks. More detail can be found either in the next chapters or in the papers.

a) <u>Task A: Coordination and valorisation.</u>

Within this task we took the following steps:

- Organisation of a scientific conference on the economic analysis of transport safety. A conference report has been published as: Louis Visscher (2003), "Werk in uitvoering: verslag van een economische conferentie over verkeersveiligheid", Verkeersrecht, 51(7/8), p. 225-232. (Ghent University – 26/02/2003)
- Organisation of meetings with user committees
- Organisation of a seminar by John Peirson – The economic theory of road accident externalities: why safe drivers should pay more (K.U. Leuven – 07/05/04)
- Organisation workshop dealing with the main results of the project (K.U.Leuven - 18/04/06)
- Presentation results on various national and international conferences
- Publication of results in various scientific journals. For a full list of the papers we refer to section 1.2.3.
-

b) <u>Task B: Overview and selection measures</u>

For this task two papers were written.

The goal of the first paper is to give an overview of the different measures that have been taken in Belgium. We give a general overview of the current traffic safety policy, sketching the broad lines without going too much into detail. We start with a description of the current level of safety in Belgium. Secondly, we give an overview of the competences of the different authorities. Because Belgium is a federal state, the political competences are divided between the federal (national) level, the regional level and the municipalities. Next, we turn to the different measures. We discuss the main categories, i.e. we look at regulation and its enforcement, liability rules, the insurance system, education and sensitisation, economic instruments, and infrastructure.

A second paper makes a general overview of possible measures to improve traffic safety. Some instruments focus on making driving a car, riding a bike or walking safer, other instruments are aimed at a change in behaviour, for example by changing the travel patterns. In this overview we only focus on the safety effects. However, some instruments can also be used to internalise congestion, noise, and environmental costs. We discuss the following categories: regulation and enforcement, infrastructure, technology, liability, insurance, education and sensitisation, economic instruments, and ‘other’.

c) Task C: Theoretical analysis

For this task we analysed some instruments which are aimed at improving traffic safety. The focus lies on liability rules and regulation and its enforcement.

For **liability rules** we first made an overview of the literature and analysed some of the fundamental gaps in the theory of liability. Next we applied the theory on liability rules to the traffic situation. We considered one specific case, more specifically, bike/car accidents. We looked in particular at how liability rules influence the behaviour of cars and vulnerable road users. We found that the current policy of having strict liability for car drivers for this type of accidents is not optimal.

Subsequently, we compared **liability rules with regulation**. We argue that regulation is intrinsically superior to tort liability because the mix of probability and magnitude of the sanction can be freely set at the optimal level, while tort law relies on a mix set by nature, as the probability of the liability sanctions equals in general the probability that an accident occurs, and the magnitude of the sanction corresponds with the magnitude of the harm.

We then analysed theoretically the joint use of **liability, regulation, and insurance.** In fact, given the argument that regulation is superior to tort liability, we use insurance as the sole method of removing tort liability as an incentive device.

Next, we analysed the joint use of **liability, regulation, and a km tax**. This paper focused on two specific determinants of accidents: speed and the number of kilometres people drive. If there is no government intervention, people do not take into account the full cost of their driving and they will drive too fast and too much. The government can use three imperfect instruments or a combination thereof: strict liability, a speed limit and a kilometre tax. We analysed the effect on speed and activity theoretically[1] and illustrated this numerically for 3 types of roads – urban, interurban, highway, and three types of users – business, commuters and others. We calculated the private and social optimal levels of speed and activity and the levels of speed and activity under the different instruments. The welfare losses determine the choice of the instrument.

**Regulation** is widely used in traffic. Think, for example, of speed limits, technical regulation, mandatory seat belts, etc. However, regulation alone is not enough. There is a need for enforcement of regulation. We focus on the enforcement of repeated speed offenders and on the choice between probability of detection and the level of the fine. A first paper makes an overview of the literature on repeated offenders.

A second paper applies this literature to **repeated speed offenders**. When we consider the current practice in Belgium we find evidence that fines for traffic offences are indeed increasing with the number of previous offences. However, the first paper made clear that the literature on this is mixed. We start from the idea that there is a positive relationship between previous convictions and the probability of being involved in an accident. The idea behind it is the following. Drivers differ in their skills, risk taking,… This makes that drivers differ in their propensity to have an accident. This means that for the same level of speed, the probability of being involved in an accident is higher for a ‘bad’ driver than for a ‘good’ driver. The government does not know who the bad drivers are, but previous speeding violations may act as a ‘signal’ for being a bad driver. Moreover, enforcement exists of two elements: the probability of detection and de magnitude of the fine. Optimally[2] the probability of detection and the fine should be such that

$$\text{fine}=\frac{\text{expected damage due to speeding}}{\text{probability of detection}} \quad (1)$$

We conclude that the optimal fine is a function of speed and equals the expected accident costs due to speeding, corrected for the probability of detection. For the same speed and same probability of detection, bad drivers have higher expected accident costs, and should therefore be fined more severely.

[1] The model is based on Shavell (1984)

[2] For an overview of the literature on optimal enforcement we refer to Polinsky and Shavell (2000).

A third paper deals with the **political economy of the fine structure for speeding**. In Europe, we see at present large variations in the magnitude of the fines and the probability in detection. Moreover we see that in general the public debate emphasises increasing the probability of detection in stead of increasing the fines. This conflicts with theory (Becker 1968) prescribing that fines should be set at the highest level and that monitoring, given the costs, should be set as low as possible. We can think of two reasons why enforcement is as it is. Firstly, high fines are not a very popular measure. Politicians, who want to be re-elected, take this into account in setting their policy. A second reason is that there are lobby groups at work. Think, for example, of the automobile industry, vulnerable road users action groups, etc. We use the second approach and analyse the choice between the inspection probability and the level of the fine for speeding given a fixed expected fine. We first calculate the socially optimal fine and then analyse the different combinations of the probability of detection and the level of the fine subject to this socially optimal expected fine. Following Dixit ea. (1997) we derive three equilibriums by maximising an objective function equal to a weighted sum of a social welfare function and the utility functions of the lobbying groups. In the benchmark case, lobbies have no influence. In the other two extreme cases, first the vulnerable road users get all the weight and subsequently, the strong road users. We find that if only vulnerable road users are taken into account, the fine is higher and the inspection probability lower than the social optimum. We find the reverse result when only car drivers are taken into account.

d) <u>Task D: Evaluation of measures to improve traffic safety: applications</u>

Besides the applications which illustrate the theoretical research, two papers were written. Both deal with the evaluation of safety measures. In order to be able to conduct a good safety policy, a good evaluation of potential measures is required. This means that one should look at all the benefits and the cost of the measures and only implement them if their benefits are larger than their costs.

The first paper deals with the calculation of a potential benefit; i.e., the total and marginal external accident cost. The aim of this paper is to present a methodology for the calculation of accident costs. This needs to be done both for the total accident cost and for the marginal accident cost. Moreover, a distinction is made between external and internal accident costs. We base ourselves on the theoretical model of Lindberg (2002) to derive the total and marginal external accident costs. From this analysis the different components for calculating the accident costs are derived. Next, we explore how these components can be calculated. For each of the components we make an overview of the existing literature, present an example and make some recommendations. The result of this work can be used as an input.

The second paper gives an example of a social cost-benefit analysis of a concrete safety measure, which is very popular in Belgium nowadays. We look at the change of a crossing with traffic lights into a roundabout. We found that the change of a crossing with traffic lights into a roundabout provides a net social benefit. The transformation makes traffic smoother and safer. The benefits of this are larger than the increased environmental cost and the cost of rebuilding. A sensitivity analysis shows that the results are very robust for changes in accident, time, and infrastructure costs. Note that the same framework can be used to make a cost-benefit analysis of other measures.

e) <u>Task E: Policy Conclusions</u>

Based on our research we make the following policy conclusions. We first want to stress that a more coherent traffic safety policy is only possible if the competences are less widespread. Moreover this will also improve the quality of the data, which is needed in order to be able to establish a good traffic safety policy. Note that a good cost-benefit analysis requires taking into account all effects of a measure, not only the safety effects. Secondly, we want to stress that more research is required with respect to influence of combined measures. Measures are never used independently; hence one must take into account their interaction effects. Thirdly, our research also showed that in general regulation will work better than tort law in a traffic safety context. It is therefore not surprising that we see so much traffic regulation. Fourthly, we plead for increasing fines for repeated offenders or for the introduction of a demerit point system. A central offenders database may in any case be worthwhile. Fifthly, we show that the current strict liability rule for accidents involving a car and a vulnerable road user is probably best replaced with the general negligence rule. Our illustrations show that if we only take into account traffic safety, it is optimal to lower the speed limit on interurban roads from 90 km/h to 70 km/h and to abolish speed limits on highways, as is the case in Germany. Finally, we want to stress that more research into the social aspects and the social acceptability of traffic safety and measures to improve traffic safety would be very worthwhile. Social acceptability is important because in the end only acceptable measures will be implemented; social aspects are important because they may plead for, for example, income dependent fines.

## 2.2. Problems

Because of maternity leave of Eef Delhaye (K.U.Leuven) work on this project paused between 13/9/2004 and 31/12/2004.

Note that the research group of Ghent stopped working for this project in 2004.

Although participation was actively sought for, the meetings with the user committee were not a great success

## 2.3. Publications

Dari Mattiacci, Giuseppe (2003), Towards a Positive Economic Theory of Negative Liability, George Mason Law and Economics research paper, No 03-29. This paper is available on http://ssrm.com/author=333631

Dari Mattiacci, Giuseppe (2004),Gödel, Kaplow, Shavell: Completeness and Consistency in Social Decisionmaking, Chicago-Kent Law Review 79(2), 497-520. This paper is available on http://ssrm.com/author=333631

Dari Mattiacci, Giuseppe; Parisi, Franceso (2006), The economics of tort law: a précis, in Backhaus, J.G. (ed), Elgar Companion to Law and Economics (2nd ed.), Elgar, 87-102. This paper is available on http://ssrm.com/author=333631

De Geest, Gerrit and Dari Mattiacci, Giuseppe (2003), On the Intrinsic Superiority of Regulation plus Insurance over Tort Law, working paper

De Geest, Gerrit and Dari Mattiacci, Giuseppe (2003), Removing and Replacing Tort Liability: A New Conception of the Social Functions of Insurance, working paper

Delhaye E. (2002), Kosten-Baten analyse van het vervangen van een geregeld kruispunt door een rotonde, Tijdschrift voor economie en management, vol. XLVII, 577-605. This paper is also available on http://www.econ.kuleuven.be/ete/research/safety.htm

Delhaye, Eef (2002), Accident analysis: The role of liability rules – pecuniary losses, working paper. This paper is available on http://www.econ.kuleuven.be/ete/research/safety.htm

Delhaye, Eef (2003), Measuring impacts on safety and accidents, working paper. This paper is available on http://www.econ.kuleuven.be/ete/research/safety.htm

Delhaye, Eef (2004), Verkeersveiligheid: Het huidige beleid in België, working paper

Delhaye, Eef (2004), Possible instruments to improve traffic safety, working paper

Delhaye, Eef (2004), Optimal enforcement of speed violations: overview literature, working paper

Delhaye, Eef (2006), Will the cyclist take care simply because he might get hurt? – The influence of liability rules in bicycle-car accidents, working paper

Delhaye, Eef (2006), The enforcement of speeding: should fines be higher for repeated offences, ETE working paper 2006-01. This paper is available on http://www.econ.kuleuven.be/ete/publications/working_papers/default.htm#WP2006

Delhaye, Eef (2006), Boetes voor snelheidsovertredingen – moeten ze hoger zijn voor recidivisten? Jaarboek Verkeersveiligheid 2006

Delhaye, Eef (2006), Traffic safety: regulation, strict liability and a kilometre tax, Transportation Research A, 40(3), 206-226. The extended version of this paper is also available as an ETE working paper 2004-07 http://www.econ.kuleuven.be/ete/publications/working_papers/default.htm#WP2004

Delhaye, Eef; Proost, Stef; Rousseau Sandra (2006), Political Economy of the Structure of Speeding Fines, working paper

# Chapter II: Instruments to improve traffic safety and current policy

## 1. Introduction

The goal of this chapter is twofold. Firstly, we give a selective overview of the main categories of instruments which the government can use to improve traffic safety. Secondly, we give an overview of current policy in Belgium. This overview only sketches some broad lines, without going too much into detail. We first give an overview of the different competences of the different governments. Because Belgium is a federal state, the political competences with respect to traffic safety are scattered over the federal (national) level, the regional level and the municipalities and provinces. Next, we take a closer look at the different instruments. We discuss the seven main categories: regulation and enforcement, liability rules, infrastructure, technology, insurance, education and sensitisation and economic instruments. Some instruments focus on making the act of driving a car, a bike or walking safer, other instruments are aimed at a change in behaviour, for example, they want to change the travel patterns. Some instruments have a very specific goal such as bicycle helmets, airbags,… while other instruments such as police controls have a wider scope.

## 2. Competences

The competences over traffic safety are widely scattered in Belgium. Moreover, the European Union also has his saying. In this paragraph we indicate the main responsibilities of the different authorities. We start with the highest level, the European Union and we end with the provinces and local authorities.

### *2.1.* The European Union

Within the European Union, the Directorate-General for Energy and Transport is responsible for

- International and European legislation to which national legislation should be conform with and adapted to (for example, the traffic signalisation).
- Harmonisation of transport policy. This means on the one hand the removal of all barriers which may limit free competition with respect to the transport of goods and persons. On the other hand, it means introducing common rules for international transport. For example, drive and rest time schedule, European drivers licence, …
- Harmonisation of technical standards.

- Research and development with respect to traffic safety and the use of new technologies. Improving traffic safety stands high on the priority list.

## *2.2.* Federal Government

Within the federal government the responsibilities with respect to traffic safety are scattered over different departments and ministries.

- The department of mobility and transport is responsible for the different regulations which deal with traffic (the traffic law, the road code,…), the registration and the inspection of vehicles, the Belgian National Rail Company, the BIVV, .the control of road signalisation on the local roads
- The Ministry of Internal Affairs is responsible for the Federal and Local Police who are responsible for the enforcement of traffic law and other legislation
- The Ministry of Justice is responsible for the legislation and the prosecution of traffic offenders
- The Ministry of Finance is responsible for V.A.T. and taxes on transport
- The Ministry of Health and Environment is responsible for the emergency service 100
- The Ministry of Economics is responsible for the National Institute of Statistics

## *2.3.* Regional Government

The Flemish Region, the Walloon Region and Brussels-Capital Region are responsible for the road infrastructure and signalisation, education (transport education in schools), research, media and communication (sensitisation campaigns), traffic management (traffic information, carpool-parking, traffic counting, winter service,…), regional public transport companies (De Lijn, MIVB and TEC), land use.

## *2.4.* Provincial and Local Authorities

The Provinces, municipalities and cities can be the owner of roads and hence are responsible for them. They also play a role in the supply of public transport and taxis. The local governments and the Provinces can set up initiatives which are aimed at education, sensitisation and enforcement. The local councils can issue laws which deal with traffic (for example, arrange a one-way street). These laws have to be approved by the Minister of Transport if they apply to provincial or community roads.

# 3. Regulation and enforcement

The most basic mechanism for attempting to influence road users' behaviour is regulation. Regulation consists of announcing a (minimum) standard and of enforcing this standard. The standard will be more effective if people are better informed about the standard and if enforcement is strong. Regulation is an ex ante approach, this is, you have to pay for violating the regulation regardless of whether you cause an accident or not. It is widely used in transport. Think of speed limits, mandatory safety belts, technical regulations, etc.

In Belgium there are three main laws[3] which govern traffic. Firstly, there is the **Traffic Law** (Verkeersreglement – Algemeen reglement op de politie van het wegverkeer). This law is meant for traffic on public roads by pedestrians, vehicles, draught animals, mounts, beasts of burden and cattle. It consists of three parts. The first part deals with the traffic rules. It gives the preconditions to drive, tells where and how to drive/walk on the different road types, how to behave with respect to other road users,… It states the parking rules and the rules with respect to lights, mirrors, helmets, safety belts, luggage…The second part deals with traffic signalisation and explains the size, the place and the meaning of traffic lights, traffic signs and the road marking. The last part deals with the technical specifications of the vehicles, the inspections,… The second law, **the Road Traffic Law** (Wegverkeerswet – Wet betreffende de politie over het wegverkeer- reglement van de wegbeheerder), gives the general legislation with respect to the police for traffic on roads by pedestrians, by animals, by transportation on land and on rails. It explains the conditions of the drivers licence and how you can obtain one. The enforcement system is also explained. It states the magnitude of the penalties and indicates how the different offences are punished and how they can be detected. Different types of possible penalties are fines, prison, licence suspension, distress on the vehicle. The third law, the **Road Code** (Straat code) is the most recent one. Its goal is to create a better protection for vulnerable road users by finding a better balance between the different road users.

The enforcement is primarily done by the federal and the local police. The focus of enforcement lies on speeding, parking offences, alcohol and the use of seatbelts. The number of assessments in Belgium is rather low. In 1999, 10.664.230 vehicles were controlled on speeding; 4.000.000 of them were speeding. However, only 356.500 notices of violation were

[3] These can be found on www.wegcode.be

issued. As a comparison, in 1999, 4.000.000 people were penalised for speeding in the Netherlands. However, note that recently Flanders invested a lot in speed and red-light cameras and hence that enforcement of speeding and red-light running has improved.

The punishment typically exists of penal fines, a licence suspension or distress of the vehicle. Since 1996, alternative sanctions, such as educational courses, are used.

# 4. Liability rules

Liability rules consist of confronting the car drivers with the real costs of their driving and by that, influencing their behaviour. The fact that you could be held liable makes car driving more expensive and thus less attractive. Under liability, you only have to pay the damages if an accident happens; it is an ex post approach.

Liability rules have two advantages over regulation. The first one is that they are also valid for problems that are not explicitly regulated. The second one is that liability also provides compensation for the victims.

There are two main kinds of liability rules[4]. The first one is strict liability. In its simplest form, strict liability dictates that if A damages B then A is liable for that damage. The second kind is the negligence rule. Under negligence, A is only liable for the damage inflicted if A has failed to exercise an 'appropriate' degree of care in carrying out his/her business. If A takes less than this due care and causes an accident, A is found liable and has to pay the damage. All other liability rules are based on one of these two.

The statutory basis of tort law in Belgium is to be found in Articles 1382 to 1386 of the Civil Code. According to the Civil Code, there is, in principle, one general rule of liability[5]: 'Any act by which a person causes damage to another makes the person through whose fault the damage occurred liable to repair such damage' (Art 1382 CC). Liability for car accidents is governed by the principles of negligence and, as the case may be, by strict liability, such as Art 1384 CC. The Act of 3 April 1995, introducing Art. 29 bis into the Act on Motor Liability

[4] For a general overview on liability rules we refer to Shavell (1987). For an application with respect to traffic we refer to Delhaye (2002)

[5] The Code does provide exceptions to the general liability rule. The position of the injured is improved by Art 1384 pars 2-4 which holds parents, teachers and masters liable without proof of fault for damages caused by their minor children, pupils and servants. In three cases, there is strict liability for things under one's control: defective things in general (Art 1384 par 1 CC), animals (Art 1385 CC) and ruinous buildings (Art 1386 CC)

Insurance, provides additional protection to pedestrians, cyclists and passengers[6]. Damages from bodily injury resulting from an accident involving a car are compensated, irrespective of fault, by the liability insurer of the car. Only an unforgivable fault of a victim older than 14 years leads to a reduction of the compensation. In fact Art. 29 bis introduces strict liability for car drivers with respect to the so called vulnerable road users. Note that Art. 29 bis only deals with bodily injuries. Everything[7] not included in Art. 29 bis follows the rules of the Civil Code.

By the Act of 1 July 1956 the liability system was complemented by a compulsory liability insurance providing unlimited[8] coverage for liability for traffic accidents. This makes that it are no longer the drivers which bear the liability, but the insurance. The behaviour of the driver will then mainly be influenced by the insurance system and less by the liability rules. We discuss the insurance system in a next paragraph.

# 5. Infrastructure

Infrastructure measures influence peoples' driving behaviour. They guide the driver on his way. Think for example of traffic calming measures (speed humps, narrowing streets, roundabouts,…), road lighting, 'self explaining roads', forgiving road environments (side barriers and roadside verges), …

In the past traffic safety did not play a major role when designing and constructing road infrastructure. Nowadays it is still no priority. If there are guidelines for the construction of roads, they are not binding and one can easily leave them aside. For the moment, the highest priorities with respect to infrastructural measures are the elimination of so called black spots and the development and use of common standards in the construction and design of transport infrastructure.

# 6. Technology

With respect to technology improvements we can think of improvements which influence the consequences of accidents (passive safety) and improvements which influence the probability of accidents (active safety). Examples of passive safety equipment are driver and passenger airbags, side airbags, restraint systems for children, optimised headrests, bicycle helmets,

[6] Drivers remain only protected by the general tort law.

[7] Material damage, compensation (bodily and material) non liable 'strong' road users.

[8] Except for material damage caused by fire and explosion (max € 1.239.467,62) and damages to clothes and luggage (max € 2.478,94/person) (Schoups et al,2000 ).

automated accident warning devices, the use of retro-reflective devices. Examples of active safety equipment are Intelligent Transport Systems (ITS) such as Anti-Break-system (ABS) and Electronic Stability Program (ESP), Intelligent Speed Adoption (ISA), Advanced Cruise Control (ACC), Distance warning devices, alcohol locks, speed cameras…

# 7. Insurance

The existing of insurance will influence the working of liability rules. The insurance company will pay if the driver is liable, hence liability will only influence the driver indirectly through the insurer. The very existence of insurance may affect accident rates adversely. This effect is not very well known, since no highly motorised country has ever had a system of no insurance. The question is how well the insurer controls the behaviour of the driver. The insurance company can use different instruments such as a bonus-malus system, per km insurance, franchise, no claim bonus in cash, … to control for the behaviour of the driver.

In Belgium a car driver can purchase three types of insurance. Firstly, there is the compulsory liability insurance – third party insurance. The insurer compensates the damages done to third parties and their personal clothes and luggage. Some people can be excluded from compensation by the insurer if there is no bodily injury. They are the driver, the insured party, the partner of the insured party, the owner of the vehicle and blood relatives. The insurer will pay the victims but will recover the damages with the insured if the accident was caused during races. The law of 25/06/92 provided a model for the contract which could only be adapted if it was in favour of the insured. Before January 2003, the tariffs and the movements in the bonus malus scale were set by law. In January 2003, Art. 38 ruling these tariffs and movements were removed. The insurer can now set his own terms. To prevent that some people can not purchase insurance any more a 'tariff office' was set up within the framework of the Motor Accident Compensation Fund. If the car driver can not obtain a payable insurance or if he is refused three times he can get insurance with the 'tariff office'. The compensation system for traffic accidents is further complemented by the Motor Accident Compensation Fund which was set up in 1975 by the liability insurers, pursuant to a legislative mandate. This Fund compensates bodily injured when the car that caused the accident cannot be identified and when a driver is victim of an accident caused by force majeure which excludes liability (sudden illness, a deer crossing the road,…). The Fund also intervenes in three cases in which the liability insurer does not provide an effective financial guarantee. This is, if there is no policy, if the accident was caused by a stolen car or if the insurer is bankrupt or lost his authorisation to practice insurance. In these three cases, all damages, up to a deductible, are compensated.

Secondly, one can also insure their own damages. For bodily damages one can purchase personal injury insurance and for material damage a material damage insurance (also called a fully comprehensive insurance). Thirdly, one can also purchase legal aid insurance. The last two types of insurance are not compulsory.

# 8. Education and sensitisation

We speak of education if the goal of the initiative, project or measure is to spread knowledge, attitudes and skills. If the only goal is to promote a certain attitude we talk about sensitisation. Education is for example traffic education in high school, basic and continuous training for private and professional drivers, …

Sensitisation, for example, may be aimed at promoting public transport, wearing the safety belt, … Note that sensitisation usually only has a temporary effect and hence need to be repeated regularly.

In Belgium, traffic education happens at primary school. In high school there is no specific course dealing with traffic education, but it may be a subject in courses such as Dutch, Geography,… or it may be the subject of a specific project.

Drivers’ education happens in two steps. First, you need to pass a theoretical exam. You can learn the theory by yourself or follow classes. Secondly, you learn how to drive. This can be done under the guidance of any adult with a licence or by following classes. This training period lasts for maximum one year and then you need to pass an exam. One only needs to succeed once.

The sensitisation campaigns are most of the time designed by the BIVV (Belgisch Instituut voor Verkeersveiligheid). Every year there are six major campaigns around traffic safety. Topics are alcohol, seatbelts, speeding, aggression, use of mobile phones,.... The campaigns use a wide mix of media such as radio and television, billboards, internet sites,… The BIVV also publishes the magazine Via Secura, maintain the BIVV and the BOB-website, and sets up other activities which may improve traffic safety.

# 9. Economic Instruments

Economic instruments, such as taxes and subsidies are in general not used to promote traffic safety. However, using an appropriate tax on driving increases the cost of an activity and hence influences the level of activity. A correct tax per kilometre makes that the driver will internalise the total accident cost. Its implementation may pose some technical difficulties, but experiments, for example London, show that it is feasible. The efficiency of this instrument depends on how finely it can be differentiated. Note that road pricing also reduces the congestion. This tends to reduce crashes but because of the increased speed, increases the severity of crashes that do occur.

Furthermore, the government can use subsidies and taxes to promote the use of a safe mode such as public transport (subsidising public transport, carpooling, removing repayments of costs of car commuting,…). Subsidies for safer cars and/or specific safety equipment will lead to higher traffic safety. They are easy to implement, but the benefits are also specific and limited.

Nowadays the Belgian government does not use any economic instrument such as taxes or subsidies to promote traffic safety. The government recently raised the taxes on fuel, not to improve road safety but to achieve the Kyoto protocol. Public transport is heavily subsidised but the underlying thought is not safety but mobility.

# 10. Conclusion

How should a government choose between these instruments? Should it choose the instruments which have the maximal potential for increasing traffic safety, the instruments which are cost-effective or the instruments with a positive benefit/cost ratio? Economically, the last option should be chosen, although this option also requires the most information. For maximal potential we need to know the effects on safety. This could be a problem for instruments, which are not in use. Think for example of the effect of road pricing on traffic safety. For other instruments, such as ISA, we can assume that there is a safety effect, since there is certainly an effect on the speed and speed affects the probability and severity of accidents. To know if a measure is cost-effective we also need to know the costs of the implementation and if there are, the maintenance costs. For a cost-benefit analysis we need to know the effect on safety, the costs and all other effects, such as time use, pollution, noise,…

That the data needs for a cost-benefit analysis are high will be clear from the example we present in chapter five about rebuilding a signalised junction into a roundabout. In the following chapters we mainly, but not exclusively, focus on two instruments: liability rules in chapter three and regulation in chapter four.

More detail can be found in
Delhaye, Eef (2004), Verkeersveiligheid: Het huidige beleid in België, working paper

Delhaye, Eef (2004), Possible instruments to improve traffic safety, working paper

# Chapter III : Liability rules

In this chapter we discuss the working of liability rules. We first discuss, based on the existing literature and our literature overviews, the consequences of different liability rules for traffic accidents when people are risk neutral. Next we confront the actual liability rules in Belgium with the theoretical optimal policies, taking into account that people are risk averse. Thirdly, we discuss the use of liability rules versus regulation and the joint use of liability rules, regulation and insurance. We end this chapter by analyzing the joint use of liability, regulation and a km tax.

## 1. Transport safety: the role of liability rules

### *1.1.* Introduction

In general, liability rules determine who pays for the damage done if an accident occurs. Therefore the expected liability enters the decision making process of the road users and influence their behaviour. Hence, the liability rule in place influences traffic safety. Shavell (1987, 2004) and Cooter and Ulen (1997) provide very comprehensive overviews of the influence of liability rules in general.

### *1.2.* Model

We first consider the consequences of different liability rules in victim-injurer accidents. These are accidents in which only one party has losses. Then we look at a model where both parties have losses. The losses are assumed to be purely pecuniary. We want to know the conditions under which liability rules reduce efficiently the accident costs of society. For both models we consider the case in which people are risk neutral and then introduce risk adversity and insurance. For the victim-injurer model with risk neutral agents we also look at what happens if we relax some assumptions.

In the first model, a victim-injurer model with risk neutral agents, in which both parties can influence the probability of an accident, there exist rules that lead to efficient care levels for both parties. This is the case for all rules involving negligence. However, there does not exist a liability rule that results in optimal activity levels for both parties. This is caused by the fact that liability rules do not allow for both parties to carry the accident losses. For this model we look at what happens if we relax some of our assumptions. We find that with a rule of strict liability, an error of the court in assessing damages distorts, but random errors have no influence. With a rule of negligence, errors in setting due care distort more than errors in damages. Vague standards lead to excessive precaution. Note that administrative costs are higher per case for negligence than for strict liability. However, there are fewer cases under negligence than under strict liability.

For the second model, a victim-injurer model with risk averse parties in which only the injurer influences the probability of an accident, two conditions should be met for a socially ideal solution. First of all, the level of care and activities should minimise the expected accident losses plus the cost of care. Secondly, risk averse parties should be left with the same wealth regardless of whether an accident occurs. A social optimum can be realised under a rule of strict liability if the injurer is risk neutral or if insurers have perfect information.

In our third model both parties have losses and both can influence the probability of an accident. The social optimal level of care and activity turns out to be the same as in our first model. Again we can obtain the social optimal level of care, but none of the parties exercises the optimal activity level.

### *1.3.* Conclusion

Economic analysis has long been employed for the study of tort liability. We revisit the main contributions to the subject emphasizing the inherent impossibility for tort liability to set perfectly efficient first-best incentives to take precaution for all parties to an accident and the need to choose among second best outcomes.

This is only a first attempt in analysing the effects of liability rules. There are many possible extensions. First of all, what if the losses are not purely pecuniary. Death, invalidity… can alter the utility of the parties and this will have major consequences on our analysis. We tackle this question in the next section. Another possible extension is to complement liability rules with other instruments. We will deal with this question in the last two sections of this chapter.

## 2. Will the cyclist take care simply because he might get hurt?

### *2.1.* Introduction

When we consider the European legislation we find that in many countries a different liability rule applies for accidents between a motorised user and a vulnerable road user than for accidents between motorised users. On the one hand, a rule of negligence applies for accidents between motorised users. On the other hand, legislation determines, in general, that only the motorised road user is liable for the accident if the other party involved is a vulnerable road user. The argument used is that a vulnerable road user risks his limbs and life and therefore will be careful even though he is not liable. The effect of these so-called non-pecuniary losses are discussed by Shavell (1987, chapter 10), Arlen (1990,1992) and Visscher (1998a, 1998b). However Shavell assumes that only one party influences the accident, while it is clear that both parties - the vulnerable road user and the motorised user – will influence the accident risk. Arlen on the other hand only discusses the influence of the level of care and not the activity level. Visscher discusses accidents between a car and a vulnerable road user where both influence the probability of an accident. However, he implicitly assumes that people are risk neutral and that simply part of the accident cost of the vulnerable road user is not compensated. We take into account that both influence the probability of an accident, that the level of care and activity play a role, that a non-pecuniary loss influences the marginal utility and that people are risk averse.

Using a simple model we investigate how a strict liability rule influences the behaviour of the vulnerable road user: is the risk of life and limbs sufficient to take care or will he behave recklessly because he will always be compensated? Will this rule lead to the social optimum? Or does another rule perform better?

## *2.2.* Model

We consider accidents between a car and a cyclist in which both parties influence the probability of an accident. We assume that the accident risk decreases with their level of care and increases with the level of activity. In this setting we think of care as the level of speed, the number of times one looks into the rear mirror, etc. We assume that taking care comes at a cost and normalise its price to one Euro per km. The level of activity refers to the number of kilometres one drives. We assume that if an accident happens, the car driver only has pecuniary losses which do not affect his marginal utility, while the cyclist also has non-pecuniary losses which affect his marginal utility negatively.

People drive because this generates a certain utility. The utility depends on the wealth, the activity level and on the fact if the driver was involved in an accident or not. We assume that the wealth equals some initial wealth minus the cost of care while driving minus possible payments for accident losses.

Given these assumptions, we calculate the private and socially optimal levels of care and activity. In the private optimum, people maximise their own expected utility while for the social optimum the sum of the expected utilities is maximised. Note that the choice of care is, given our assumptions, independent of the choice of the activity level. On the other hand, the care level is taken as given in determining the private optimal activity level. If the government does nothing, there actually is a no liability rule in place. Under no liability, each party pays for his own losses. Given that both drivers influence the accident losses of the other driver, this makes that they do not take into account the full cost of their driving and exert too little care and drive too much compared to the social optimum. We do find that in the private optimum, the cyclist takes more care and drives less than the car driver because he risks life and limbs. However, he does not take socially optimal care and still drives too much. The aim of this analysis is to see to what extent the different liability rules push the drivers towards the social optimum.

We first consider strict liability. Remember that strict liability means that if an accident happens, the car driver is always liable, whatever his level of care and whatever the behaviour of the cyclist at the time of the accident. This makes that the car driver takes into account part of the accident costs he causes to the cyclist. However, he does not take into account the full accident cost because he does not have to pay for the change in marginal utility. Hence he takes more care and drives less than in the private optimum, but his care is less and his number of km is higher than socially optimal. The cyclist on the other hand is compensated for most of his accident losses, but not for the loss in utility. This makes that he takes less care and drives more than under no liability. Hence, he takes less care than socially optimal and drives too much. However, he will take some care. If we would assume that the accident does not influence his marginal utility, strict liability would make that the cyclist takes no care at all.

Secondly, we consider a pure negligence rule. Remember that this rule states that an injurer is held liable for accident losses he caused only if he was negligent, that is, only if his level of care was less than the level specified by courts, called due care. Under negligence, the behaviour is less clear because the drivers explicitly take into account the decisions of the other players. However, we proof that under certain conditions, both parties will take optimal care. These conditions mainly restrict the probabilities of an accident under different levels of care. Loosely speaking, they state that the probability if both take due care should be small enough compared to the probability if they take less than due care to compensate for the higher costs of taking due care compared to taking less than due care. If people take due care, under negligence there is no restriction on their activity level and they will both drive more than socially optimal.

Under the third instrument, comparative negligence, if only one party is at fault, that party bears all the losses. If both parties fail to take due care, each party bears a fraction of the accident losses. The fraction is determined by a comparison of the amount by which the two parties’ levels of care depart from the levels of due care. We get a similar game as in the negligence case. Only the case where both take less than due care is different, but this only changes the results marginally.

### *2.3.* Conclusion

Which liability rule then performs best when we consider car-bicycle accidents? The argument for the current rule, strict liability, is that cyclist will act carefully because they risk life and limbs. We find that there lies some truth in this argument. Because of the risk they take more care than if they would not risk their life. However the incentive is not high enough. Under strict liability the cyclist exert less than the socially optimal care and drives too much. Moreover, even the car driver takes less than optimal care and also drives too much even though he is held strictly liable. This is because he does not have to pay for the losses in utility. Furthermore we show that it is possible that we obtain the socially optimal levels of care under negligence or comparative negligence. The activity levels on the other hand will never be socially optimal. Hence we see no reason to have a different rule for car-cyclist accident and advocate that it would be more efficient to use a form of negligence rule for all types of accident.

# 3. Regulation versus strict liability

By tort law we mean the functioning of the system under which victims can claim compensation from injurers through the judiciary, according to certain liability rules. By regulation we mean those situations in which a (administrative or criminal, monetary or non-monetary) sanction is levied upon a certain behaviour by an enforcer (the police, a governmental agency, or a criminal court).

Regulation is intrinsically superior to tort liability as a device to generate incentives to take precaution; while under tort liability the probability and the magnitude of the sanction are blindly set by nature and correspond to the probability of an accident and the magnitude of the harm, respectively, regulators may attain the same expected sanction $s=pS$ by means of a virtually infinite number of combinations of $p$ and $S$. This flexibility allows regulation to respond to factors that would impair the effectiveness of the incentives produced by tort law. We do not claim that tort law is completely irresponsive to these aspects, but its receptivity is clearly limited to the setting of S, while p does not directly depend on public policy. Let us further elaborate on this point.

Under tort law, the magnitude of the sanction correlates with the magnitude of the harm. Notwithstanding, legal systems make at times an attempt to reset it. Punitive damages, undercompensation and average or inaccurate compensation of the harm are examples of instances in which the natural setting of the magnitude of the sanction is overturned by legal dictates or judicial precedents. Nevertheless, the attainability of different levels of p from the level set by nature is very limited, as p basically depends on two factors that are not in the direct control of the policy maker: the possibility for the injurer to escape detection, which mainly rests on the nature of the externality or on the context in which the externality takes place, and the willingness of victims to sue, that in turn mainly depends on the cost of litigation, the probability of success and the measure of the compensation. The cost of litigation may be determined at a policy level, and hence influence p, but the determination of the measure of the compensation will affect at the same time p and S, potentially yielding undesired outcomes. Moreover, even if p may be reduced, it is hard to imagine how p could be possibly increased over the level at which injurers pay compensation for all accidents they cause. The steadiness of p undermines the effects on the setting of S, as it ties any change in S with a correspondent change in the expected sanction s, which may in turn be undesirable in the specific circumstances. Consequently, tort law appears seriously constrained in the setting of p and S.

Regulation may instead rely on a rather uncontrived set of possibilities to determine p and S independently. The probability of the sanction depends in fact on the level of enforcement and can be pushed either beyond or below the probability of causing an accident, as police control may regard parties' levels of ex ante precaution directly, rather than being activated by the actual occurrence of an accident. Tort law, in fact, only sanctions inattentive motorists if an accident occurs, while police controlling speed limits sanction motorists in any case their speed was excessive, before and irrespective of the occurrence of accidents. Regulation may therefore set p at virtually any level between 0 (no police on the street) and 1 (an electronic speed control device on every street), while tort law may in the best scenario only set p between 0 and $p_t$, the probability that an accident occurs, which is in general lower than 1.

Concerning the sanction, not only does a regulatory approach allow for the determination of the magnitude independently of the probability, but it also caters for the need to substitute at times a monetary sanction with a non-monetary one, a choice that is generally not available under tort liability. Moreover, the implementation of sanctions through the regulatory system makes the sanction only related to the production of incentives and tailored on the violators’ behaviour only, while the compensation of victims may be left to the insurance system. Tort law inevitably groups these two functions together with unavoidable conflicting tendencies. Furthermore, the regulatory approach allows to deal with the risk attitude of parties in a more specific way, as violator are considered while setting the probability and the magnitude of sanctions, while victims are considered while setting the modality of harm compensation. Again tort law only provides for the allocation of risk to a party or another, while the curbing of risk generally dilutes incentives.

# 4. Liability and Regulation and Insurance

## *4.1.* Introduction

In this section, we analyze insurance as the sole method of removing tort liability as an incentive device when tort liability is unable to optimally balance incentives, risk allocation and transaction cost minimization. Once removed, tort liability may be replaced by a system of public enforcement or by the delegated control of the insurer. In addition, we examine to what extent insurers may correct the deficiencies of tort liability. Also discussed is the residual role of tort law once the parties have been insured.

Hence we analyse the effect of three legal areas on peoples’ behaviour: accident (tort) law, regulation (and criminal law) and insurance. In our view, regulation is the area that is more important in traffic accident prevention and hence the area on which the main attention of the policy maker should be focused, as it provides better incentives than tort law. Tort law and insurance play a subsidiary, though very important role, and should be also taken into careful account, but in a different way than the literature has till now proposed.

The structure of our discussion below will be as follows. Starting from the argument that regulation is to be preferred over liability rules, we show that if tort law is to be removed and substituted with regulation, mandatory insurance ought to be implemented. In order to remove the sanction system generated by tort law, both parties to an accident ought to be delivered from the accident loss. Insurance bears this task. In our view, what has been always seen as a deficiency of insurance – the dilution of incentives created by tort law – becomes its strength. Next, we further elaborate upon these two main points and study the reciprocal relationships between regulation and insurance, on the one hand, and insurance and tort law, on the other. We show that if law enforcement through regulation requires insurance to remove tort law, insurance cannot function as a general delegated control system in the absence of regulation, for economies of scale, public-good problems and perverse incentives for the insurance industry to collude. Moreover, insurance eradicates tort liability from the parties’ interaction, but liability rules (including no liability) remain an irremovable device to split costs among insurers. In this sense residual tort law should be set in such a way to minimize the administrative costs of the insurance system. We will then study the financing of the insurance system as a way to control parties’ activity level, which is closely related to corrective taxation. In the last part of our study, we address issues concerning the administrative costs and the information requirements of the regulation and tort system and derive the conditions under which these costs make the implementation of the regulation-plus-insurance model unfeasible, leaving room for tort law or tort law and regulation combined.

## *4.2.* Insurance as a way to remove tort liability

If control over people’s production of negative externalities is to be passed from tort law to regulation in order to readjust p and S at different levels from those set by nature, tort liability must be removed. From a legal perspective the removal of tort law corresponds to the absence of liability. However, as the function of tort law is to determine which party should bear the accident loss, no liability simply means that the loss will be borne by the victim. In an economic perspective no liability is a liability rule along strict liability, simple negligence, comparative negligence and so forth. The only difference is in the party that bears the accident loss. Moreover, tort liability does not remove the loss from the victim, but it simply reallocates it, if this is the case, to the injurer.

In order to remove completely the incentives produced by tort law and clear the field for the functioning of regulation, the accident loss should be eradicated, in the sense that neither the victim nor the injurer should bear it. Mandatory insurance is the solution, as it may provide compensation to the victim – thus removing the loss from him – without charging it onto the injurer. Insurance works under any liability arrangements, as it can be always designed to cover the liability or the accident loss borne by the liable party, being that party either the injurer or the victim.

By mandatory insurance we mean a (publicly or privately organized) system that provides compensation to the victim in the case of an accident, so that neither party has to pay for it. The fact that either party might be required to pay for the insurance coverage does not affect the incentives as the choice of the level of precaution usually intervenes after the insurance premium has been paid. Nevertheless, the financing of the insurance coverage will be considered in the proceeding in two respects: the control of parties’ activity level and the function of insurance as delegated control system potentially competing with regulation. In the latter perspective we will account for the moulding of the premium to the behaviour of the insured and the direct monitoring of the behaviour itself. Insurance ought to be mandatory for at least two reasons: adverse selection might impair the functioning of insurance and private incentives not to buy an insurance coverage might yield the same result.

## *4.3.* Regulation as a way to enable the functioning of insurance

Mandatory insurance can be regarded as a delegated control system inasmuch as the insurer is able to influence the insured's behaviour through adjusting the premium to past behaviour or directly monitoring it. The question is whether the insurance is able to organize a system of control for insured's behaviour and interested in doing so; insurers could act as enforcers and hence render regulation superfluous. Put metaphorically, police officers might be paid by the insurance companies rather than by taxpayers. In a competitive insurance market, there exist incentives for individual insurance companies to set up efficient systems of control so to improve the insured's behaviour and reduce the price of the coverage.

Controlling people's behaviour shows at times economies of scale (one unique electronic speed-control device that monitors all motorists cost less then as many devices as many insurance companies each of which only monitors the motorists insured with a specific company) and public good problems (a police officer hired by company A might serve as a deterrent for the motorists insured with company B and C, from which it would be difficult to collect). For the former two reason is seems in general more desirable to have a unique and centralized system of control, although the question remains of whether such system should be paid by the insurance industry or by the tax payers.

It seems that the insurance industry as a whole would not have sufficient incentives to set up and manage such system, even after leaving aside collective action problems that might impair the grouping of the interests of different individual companies. In fact, both the cost of administering the control system and the cost of not having the system at all (in terms of greater accident losses) would be ultimately paid by the insured, in terms of higher premiums. We shall conclude, thus, that a centrally and publicly organized control system is necessary in order to provide incentives to take precaution in the first place and lower the cost of the insurance system as a consequence. We shall account in a next section for the role of some residual incentives that may be produced by individual insurance companies by means of bonus-malus or similar clauses and their interaction with regulatory incentives.

## *4.4.* Tort liability as a way to lower the administrative costs of insurance

We have said that insurance removes tort liability and frees parties from the incentive effects thereof. However, tort liability remains inevitably in place as a rule that allocates the accident loss among insurance companies. Again we must emphasize that no liability simply allocates the loss either to the insurer or to the victim. What should then be the criterion for the setting of liability if incentives are no longer a concern for this area of the law? Our contention is that liability rules should be designed in order to reduce the administrative costs of the insurance system, as they are irrelevant for the parties' behaviour in the presence of full insurance coverage.

It has been observed that the insurance system is a much cheaper system than the liability system as a way to provide injured parties with compensation. The designing of tort liability might reduce even further such costs by catering for simple and easily applicable rules, avoiding the implementation of complex negligence inquiry and curbing litigation by enhancing certainty and foreseeability of the rules.

## *4.5.* Financing the insurance coverage and exposing insured to risk as ways to control the activity level

In the economic literature on tort law, the efficiency of different liability rules is commonly discussed in relation to two elements: the level of care and the level of activity. Activity level and care are different forms of precaution and the split between the two resides in the judicial inquiry over parties' negligence. The precautionary measures that are investigated while deciding issues of negligence are to be considered as care. In car accidents for example, speed, condition of the brakes and stopping at the zebra crossing are likely to be considered by the judge while deciding whether or not the motorist is to be considered at fault. However, not all precautionary measures are included into the negligence inquiry, as some of them are extremely difficult or costly to measure. The determination of negligence is for example likely not to be a question of whether or not a motorist used correctly the rear mirror, or of whether or not it would have been more desirable to leave the car at home and use public transportation (an extreme form of precaution, after all).

Likewise, regulation cannot in general target all the parties' precautionary measures and some of them will escape enforcement. Also with respect to regulation, therefore, we can speak about a set of precautionary measure that will remain untaken and that we can denominate as activity level, for homogeneity with the results attained in tort law and economics. The problem of how and to what extent incentives should be provided with respect to the activity level will be discussed here. We wish to emphasize two points.

First of all, the economic theory of torts has found that, under normal tort liability, incentives to reduce the expected accident loss by adjusting the activity level are produced by the bearing of the residual loss, which is the accident loss that anyway occurs albeit the parties were non-negligent. The party that bears the residual loss has incentives to curb the level of his activity and in general to take precautionary measures that escape the negligence inquiry. Likewise, under regulation, parties have incentives to take precautionary measures that escape apprehension if they bear some costs in the event of an accident.

This result suggests two possible solutions. A sanction could be imposed upon occurrence of an accident irrespective of whether parties have previously complied with the regulatory requirements. The sanction could be actually imposed through the insurance system by means of an increase in future premiums. In this respect, insurance companies might enjoy lower costs than a centralized regulatory system, as apprehension would be granted by the fact that the insurance is called upon while compensating the victim and hence the increase in the premium of the insured will be attained at very low administrative costs, presumably lower than the cost for the enforcer to do the same. A straightforward way to do so might be the commonly used bonus-malus clause. In this respect, competitive forces will drive insurance companies to set ex post sanctions efficiently, as to attract consumers. It is also sensible to believe that a graduation of the ex post sanction according to the causal contribution to the accident will yield positive results in terms of accident prevention and, hence, cost of the insurance coverage. In the economic literature on tort law, the importance of a correct determination of the issue of causation has been defended as well as the advantages of sharing the residual burden among causally co-responsible parties, both in order to overcome problems of causal uncertainty and to control the activity level of different parties simultaneously, rather than focusing on one party only. These arguments suggest that the same might apply to the charging of increased premiums to those parties who cause more accidents.

A second important point is how the insurance coverage should be financed. There are three main possibilities: the injurers should buy third-party insurance, the victims should buy first-party insurance or they should both contribute to the system in the same measure (for example the insurance could be paid by taxpayers and be publicly provided). This issue also affects the considerations made supra, and the need to control either party activity level bears on the choice of the financing system. Moreover, while the first solution disincentivizes injurers (in car accidents, for example, compulsory third-party insurance increases the overall cost of driving), the second disincentivizes victims (in car accidents, for example, it increases the cost of being a pedestrian), while the third method is rather neutral.

Therefore, the choice of how to finance the insurance coverage should be guided by consideration about the desirability of certain activities in the first place. The same issue, however, can be addressed from the point of view of the administrative costs that it triggers. It has been remarked that a system of first-party insurance might have lower administrative costs and for this reason some countries have abandoned the traditional injurer-pays paradigm and opted for a generalized first-party insurance system.

## *4.6.* Administrative costs, information and mixed solutions to the problem of providing incentives to take precaution

In this section we address the issues of the information requirements of alternative incentive systems and the administrative costs thereof.

**Information costs**

It is often maintained that a tort law system, being based on a decentralized decision process, is more efficient with respect to gathering information than a regulatory and hence centralized system. In particular, under strict liability the optimal level of precaution is selected by the injurer and the legal and judicial systems need not to collect any information concerning it. However, once a negligence rule is in place, the due level of care must be set by the judiciary, the legislature or a regulatory body and the informational advantage of tort law only remains inasmuch as liability rules allow an individualized setting of the negligence criterion by the judge and parties are well placed for the ex post production of the relevant information and the ex ante prediction of the due level of care that will be applied in the case of litigation.

When parties are rather uniform in terms of costs and benefits, the individualization of the due level of care is too costly, or the production and acquisition of information are better dealt with at a centralized level, regulation appears to gain an advantage over tort liability also in terms of information costs.

Traffic safety may provide with a convincing example of a situation in which a centralized traffic authority is better placed than individual motorists, bicyclists and pedestrians, on the one hand, and judges, on the other hand, for the determination of the optimal levels of precaution. Moreover, the optimal levels of precaution seem to be very similar if not identical for injurers and victims within a certain class, and there might still be the possibility to differentiate among different classes of individuals (children, bicyclists, pedestrians, lorry drivers, car drivers, and so forth).

**Administrative costs**

Regulation triggers high enforcement and sanctioning costs, and insurance is costly to administer, but tort law is rather costly an incentive device too. Courts trigger a cost that can only be avoided by implementing no liability; lawyers' fees and the overall time and energy that parties spend in litigation or settlements amount to a social cost. Empirical studies have revealed that compensating victims through liability has an enormous cost if compared with the cost of compensating victims through insurance. Moreover, the administrative costs of collecting fines or in general imposing sanctions are supposedly lower than the costs of making injurers pay damage compensation.

It is also true however, that some litigation might arise even in the presence of regulation plus insurance and that residual tort law will still yield a cost, albeit the determination of liability between litigants seems to be a simpler problem if the litigants are insurance companies rather than individuals.

It is again an empirical question whether in specific circumstances the overall administrative costs of a system based on regulation and insurance overcome the advantages in terms of more efficient accident prevention and total removal of risk from individual parties. It is conceivable, however, that regulation plus insurance will be superior in situations in which the number of parties is large, the technology is known by the regulatory body, the optimal mix of probability and magnitude of sanctions lies far away from the natural levels set by tort law and parties are seriously risk averse. Traffic safety seems again to match these requirements.

**Extreme versus mixed solutions to the problem of accident prevention**

When the requirements discussed above are not met, there will still be situations where the optimal solution is provided by tort law, as the administrative costs of implementing a centralized regulatory system might be too high, as for example for activities that are rarely practiced, or are practiced by few individuals and do not yield particular risks or employ a new technology on which information would be difficult to acquire by regulators. Moreover, the literature has emphasized the existence of cases in which combining regulation and liability yields an improvement in terms of accident prevention. The joint use of regulation and liability will be discussed in the next section.

# 5. The joint use of regulation, strict liability and a kilometre tax.

## *5.1.* Introduction

In this section, we focus on the joint use of regulation, liability and economic instruments to control accident risks. The theoretical analysis starts from the work by Shavell[9], which is applied to traffic safety and extended by including the activity level. We also provide an empirical example and introduce enforcement.

## *5.2.* Method

We only consider unilateral accidents. Only one party, the injurer, can prevent the accident and the other, the victim, bears all the losses. We assume that the losses can be expressed as purely pecuniary. For the individual, the private cost of driving is a decreasing function in speed and increasing in the value of time. We assume that people differ in their value of time and that the government only knows the distribution of the value of time.

We assume that only two elements determine the accident cost: speed and the activity level, this is the number of kilometres one drives. As speed is a major determinant in traffic accidents, we assume that the probability of an accident only depends on speed. We assume that the harm caused by the accident is fixed. The number of kilometres on drives provides a utility for the individual but it also raises proportionally the private and the accident costs.

## *5.3.* Results

Given these assumptions we first calculate the private optimal speed and activity level by minimizing the private cost of driving. Next we calculate the social optimal levels by minimizing the social cost of driving; this is the sum of the private cost and the expected harm. We get a level of speed which is lower than the private one and which is increasing in the value of time and decreasing in the value of the harm. The social level of activity is smaller than the private level and decreasing in both the value of time and the value of harm. Hence if there is no government intervention, people do not take into account the full cost of their driving and they will drive too much and too fast.

The question for the government is which instrument to use to let people drive the social optimal level of speed and activity.

We first calculate the levels of speed and activity under the use of liability alone. The rule is strict liability, this is, if an accident happens, you have to pay for the damages. Since we

[9] Shavell, S (1984)

assume that the probability of prosecution is smaller than one and since we introduce a positive probability that the injurer cannot pay for the full damages[10], strict liability will lead to a level of speed and a level of activity which are higher than socially optimal. Secondly, we look at the use of regulation alone. Optimally, the government should set different speed limits for people with different values of time. However, we assume that the government only knows the distribution of the value of time and hence, as we also see in reality, it will set a uniform level of speed. Hence, some people drive too fast and others too slowly. Regulation is in general not used to control the activity level. An instrument which influences the activity level directly is, for example, a tax on the number of kilometres one drives. However, a kilometre tax used alone will only influence the activity level and not the speed. Given that the tax will, as the regulation, be uniform, it will not lead to the social optimum. Joint use of instruments can perform better, but will also not lead to the socially optimal level. Which instrument or which combination performs best depends on a number of factors such as the harm done, the assets of the driver, the distribution of the value of time and the performance of strict liability. We should compare the welfare losses under the different measures. Theoretically the results are not clear-cut. Therefore we illustrate this theory with a numerical example.

Note that in the basic analysis we assume that people comply with the regulation. This is of course not realistic. We relax this assumption and consider the optimal enforcement problem. We calculate the optimal fine, probability of detection and the speed limit. We find that the speed limit is stricter if there is no full compliance.

## *5.4.* Illustration

The theory is illustrated by means of a numerical example. We consider three types of drivers (c= commuters, b= business men, o= others), and hence three values of time. For the three groups we calculate the private optimum, the social optimum, the levels of speed and activity under strict liability and the speed limits if regulation is used alone or jointly with strict liability. We also calculate the optimal taxes for the different combinations. Next we calculate the welfare losses under the three instruments and some combinations of instruments and derive which system performs the best given our assumptions. The results are given in Table 1.

[10] In the literature this is called the judgement proof problem.

**Table 1 : Welfare losses (euro/driver)**

| Welfare losses | Social | Private | Strict liability | Regulation |
|---|---|---|---|---|
| Highway | 0 | -69 | -11 | -76 |
| Interurban | 0 | -2.345 | -182 | -127 |
| Urban | 0 | -2.694 | -243 | -222 |

| Welfare losses | Tax | Tax + Strict liability | Tax + Regulation | Regulation + Strict liability |
|---|---|---|---|---|
| Highway | -64 | **-10** | -72 | -10 |
| Interurban | -1.965 | -169 | **-92** | -167 |
| Urban | -1.771 | -213 | **-92** | -248 |

Own calculations

If we look at total welfare losses, we see that for urban and interurban roads they are the smallest under regulation and a km tax, and the highest – except for the private optimum – under a km tax used alone. For highways we find that strict liability and a km tax performed best. This would suggest the abolishment of speed limits on highways, which is the case on some highways in Germany. To test the robustness of our assumptions we perform a sensitivity analysis. Crucial factors are the probability of conviction, the assets versus the harm and the variability of the values of time.

## *5.5.* Conclusion

In the end, the government can choose between three measures, strict liability, regulation and a kilometre tax, or any combination of them. The choice should be made by minimizing the social losses.

More detail can be found in

Dari Mattiacci, Giuseppe (2003), Towards a Positive Economic Theory of Negative Liability, George Mason Law and Economics research paper, No 03-29.

Dari Mattiacci, Giuseppe (2004),Gödel, Kaplow, Shavell: Completeness and Consistency in Social Decisionmaking, Chicago-Kent Law Review 79(2), 497-520.

Dari Mattiacci, Giuseppe; Parisi, Franceso (2006), The economics of tort law: a précis, in Backhaus, J.G. (ed), Elgar Companion to Law and Economics ($2^{nd}$ ed.), Elgar, 87-102.

De Geest, Gerrit and Dari Mattiacci, Giuseppe (2003), On the Intrinsic Superiority of Regulation plus Insurance over Tort Law, working paper

De Geest, Gerrit and Dari Mattiacci, Giuseppe (2003), Removing and Replacing Tort Liability: A New Conception of the Social Functions of Insurance, working paper

Delhaye, Eef (2002), Accident analysis: The role of liability rules – pecuniary losses, working paper.

Delhaye, Eef (2006), Will the cyclist take care simply because he might get hurt? – The influence of liability rules in bicycle-car accidents, working paper

Delhaye, Eef (2006), Traffic safety: regulation, strict liability and a kilometre tax, Transportation Research A, 40(3), 206-226. The extended version of this paper is also available as an ETE working paper 2004-07

# Chapter IV: Regulation

In this chapter we focus on the regulation of speed offenders. We first analyse, for a given probability of detection, whether fines should be higher for repeated offenders. Next, we analyse the setting of the probability of detection and the level of the fine in a political economy model.

## 1. Should fines be higher for repeated speed offenders?

### *1.1.* Introduction

Speed limits are a well-known instrument to improve traffic safety. However, speed limits alone are not enough; there is need for enforcement of these limits. Enforcement, typically, consists of two elements: the probability of detection and the magnitude of the fine. Table 1 shows the existing Belgian fine structure for speeding offences.

**Table 1 : Structure of fines for speeding**

| Speeding | Average immediate collection (€) | Court (€)[a] | Licence suspension |
|---|---|---|---|
| < 10 km/h | 50 | 55-1375 | No[b] |
| 10-40 km/h | 128 | 110-2750 | Possible |
| + 40 km/h<br>(+30 km/h)[c] | Court | 220-2750 | At least 8 days<br>(5 years) |

www.wegcode.be
a: doubles if repeated offence + administrative guidelines: take into account history
b: possible after 3 convictions
c: school environment/30 km/h zone

We make two observations. First, the fine increases with the severity of the violation. Secondly, the fine depends on the speeders’ offence history. The first result is common in the standard literature. If the goal is to maximise social welfare, the probability of detection and the fine should[11] be such that

$$fine = \frac{\text{expected damage due to speeding}}{\text{probability of detection}} \qquad (1)$$

[11] Polinsky and Shavell (2000)

The faster you drive, the higher the expected damage and hence, for a given probability of detection, the higher the fine should be. For the second result, there is much more controversy. Increasing fines in the offence history are often found in the real world, but are still a theoretical puzzle. The results are mixed: depending on the assumptions we found increasing, decreasing or constant fines. There are two intuitive reasons for having increasing fines. Firstly, fines may increase because of imperfect detection. Secondly, fines may increase because the damage is not identical for all individuals and your record gives information about your damage. These can be found back in the literature. Literature (Polinsky and Shavell (1991), Harrington (1988), Landsberger and Meilijson (1982)) mostly focuses on under deterrence. The problem with applying this literature to traffic safety is that it focuses on increasing the probability of detection rather than the fine and it is hard to monitor one driver more than another. We use the second approach, also used by Polinsky and Rubinfeld (1991), and use the signalling function to explain increasing fines.

Our idea for having offence dependent fines is the following. We state that people differ in their ability to follow the rules and in their propensity to cause an accident. This is, there are good and bad drivers and bad drivers can speed by accident even if they want to comply. Moreover, the expected accident cost for bad drivers is higher than for good drivers. Equation (1) then prescribes that bad drivers should be fined more severely than good drivers. The government does not know who the bad drivers are, but previous accidents and speeding violations may act as a ‘signal’ for being a bad driver. The literature[12] on the relationship between previous convictions and the probability of being involved in an accident typically finds a positive relationship.

We confront two fine structures, both increasing with speed: a uniform fine and a differentiated fine, which depends on the offence history. We do not look for the optimal structure, but merely compare these two systems.

## *1.2.* Model

We consider unilateral accidents, this is, accidents in which one party causes the accident and the other party has all the losses. Think for example of an accident between a car and a bicycle on an interurban road. We distinguish two types of drivers, good and bad ones, which differ in their ability to comply with the regulation and in their expected accident costs. The probability of an accident increases with the level of speed and depends on the type of the driver. For a given level of speed, the probability of being involved in an accident is higher

[12] Gebers (1990), Boyer et al (1991), Stradling et al (2000), Dagneault et al (2002), Gebers and Peck (2003)

for bad drivers than for good drivers. Drivers also differ in their ability to comply with regulation. A good driver who wants to comply will comply. We assume that bad drivers who want to comply can still speed unintentionally. We assume that all drivers think that they are good drivers[13]. Hence, bad drivers make decisions as if they are good drivers. The government only knows the distribution of good and bad drivers but not the individual driver types. We further assume that drivers are risk neutral.  The car driver determines his level of speed by minimizing his expected costs, which consist of the resource cost, the fuel cost and the time cost. If the government does not intervene, the driver does not take into account the expected accident cost and drives too fast. The social optimum takes into account the accident losses and prescribes that bad drivers should drive slower than good drivers because they have higher expected accident costs. The government can bring the private optimal speed closer to the socially optimal level by the use of liability rules, infrastructure, vehicle regulation or speed limits. We focus on the use of a speed limit[14].

Optimally, the government should set a different speed limit for the different types. Given that the government cannot distinguish the drivers, it sets a uniform speed limit taking into account the distribution of drivers. However, if there is no enforcement no one will comply.

A uniform fine, equal to the expected accident cost over both types of drivers, makes that good drivers are fined too harshly and bad drivers not enough. The uniform fine makes that both types want to comply with the speed limit and hence that good drivers drive slower and bad drivers drive faster than socially optimal.

For the differentiated fine, we set the fine for a first offence equal to the expected accident costs for a good driver and the fine for a second offence equal to the expected accident cost for a bad driver. The government does not know who the good and the bad drivers are. However, it does know that there is a positive relationship between the number of previous convictions and the probability of an accident. Therefore, the drivers are divided into two groups: a group with no record and a group with a record. A driver gets a record if he caused an accident and/or if he is caught speeding. If a driver is not caught and he did not cause an accident, after a period of time his record is cleared. This system makes that good drivers with a record will comply, that bad drivers with a record will try to comply but that some of them will speed and that all drivers without a record drive at the socially optimal speed level for

[13] This is not a very strong assumption. In general people overestimate their abilities. Svensson (1981) showed that 80% of the drivers think that they are above average drivers.
[14] We refer to Delhaye (2006) for the influence of regulation and/or liability on speed.

good drivers. This system also does not work perfectly because there is no perfect correlation between the type and between (not) having a record. There are bad drivers in the 'no record group' and good drivers in the 'record group'. Note that we can describe the movements in and out the two groups as a Markov chain. Hence we can calculate the different proportions in equilibrium. The best structure is the one with the lowest welfare losses. However at first sight it is impossible to see which system performs best. The choice will depend on the different parameters.

## *1.3.* Illustration

We illustrate this by means of a numerical example, which looks at two things. First, we calculate the optimal values for the speeding fines and compare these with the existing fines in Belgium. The results are shown in Table 2.

**Table 2: Comparison with the existing structure**

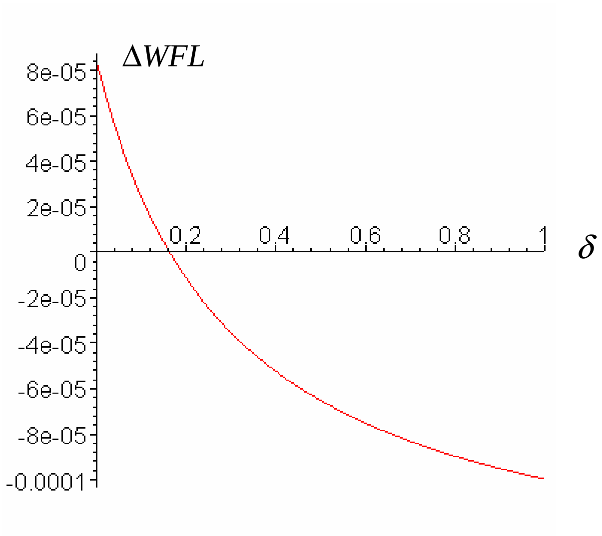
| | Present structure | Results | | |
|---|---|---|---|---|
| Speeding | Average immediate collection (€) | Uniform fine (€) | Differentiated fine (€) | |
| | | | Fine no record | Fine if record |
| < 10 km/h | 50 | 50 | 44 | 71 |
| 10-40 km/h | 128 | 89 | 79 | 125 |
| + 40 km/h | court | 255 | 226 | 360 |

Source: wegcode.be, KB 30 September 2005, own calculations.

We find that if the probability in Belgium of being caught speeding equals 1 percent, the current fines approaches our optimal fines. For larger offences, the current fines increase more steeply in the level of violation than the calculated fines.

Next, in order to compare these two fining systems, we need to calculate the welfare losses. We let the probability of detection free. We first assume that 80 % of the drivers are good drivers, that the probability that bad drivers speed unintentionally equals 40% and that the probability to return to the 'no record group' equals 30%. The last figure means, for example, that you move to the 'no record group' after three years if you were not caught or did not have an accident during these three years. Given this information we calculate the difference in social welfare, $\Delta WFL$ (welfare losses uniform fine minus welfare losses differentiated fine). The result is given in Figure 1.

**Figure 1: Difference in welfare losses**




The optimal structure switches for a certain probability of detection. We see that if the probability of detection is smaller than 16%, the differentiated fine performs better than the uniform fine. Otherwise, the uniform fine performs better. It is hard to know the real probability of detection in Belgium, but it will most likely be lower than 16% per trip[15]. In this case we should prefer a differentiated fine. The reason why we prefer a uniform fine if the probability of detection rises is that if the probability of detection increases, the proportion of good drivers with a record also rises. Moreover, the probability of clearing the record is only 30%. Hence, once a good driver has a record it keeps that record for a long time. If on the other hand the probability of clearing the record rises to 60%, the differentiated fine performs better as long as the probability of detection is lower than 0.36. Hence, the probability of detection under which the differentiated fine performs better increases in the probability of clearing the record.

## *1.4.* Conclusion

In this section we focus on the structure of the fines and on repeated offences. We do not look for the optimal structure, but merely compare two systems: a uniform fine and a fine dependent on the offence history. Our rationale for having offence dependent fines is the

[15] We can obtain such a high probability of detection for certain areas by the use of automated speed control. However, it would be infeasible to obtain on a large area such as Belgium as a whole.

following. People differ in their ability to follow the rules and in their propensity to cause an accident. This is, there are good and bad drivers and bad drivers can speed unintentionally even if they want to comply. Moreover, the expected accident cost for bad drivers is higher than for good drivers. Standard theory then prescribes that bad drivers should be fined more severely than good drivers. However, the government does not know who is a good and who is a bad driver. The literature shows that there is a relationship between the probability of being involved in an accident and the number of previous offences.

A uniform fine makes that good drivers are fined too harshly and bad drivers not enough. However, the differentiated fine system also does not work perfectly because there is no perfect correlation between the type and the group. There are bad drivers in the 'no record group' and good drivers in the 'record group'. The choice between these two systems depends on how good the relationship between the type of the driver and the record of the driver is.

We make a numerical illustration, which looks at two things. First, we calculate the optimal values for the speeding fines and compare these with the existing fines in Belgium. We find that the current fine structure increases faster than our calculated fines. We also find that for the current fines to be optimal, the probability of detection should be around 0.9% per trip. Further, we also study the critical values for the probability of detection, which determine the choice between the two fine structures. The analysis shows that for reasonable values for the probability of detection a differentiated fine should be preferred.

# 2. The political economy of the structure of speeding fines

## *2.1.* Introduction

In Europe, we see at present large variations in the magnitude of the fines and the probability in detection. For example, in Belgium in 1999 10,6 million vehicles were monitored on speeding and around 4 million offences were registered. However, only 346.500 notices of violation (NOV) were drawn up (Deben 2003). In the Netherlands, on the other hand, 4 million speeding offences were sanctioned (Komino 2002). Even within countries, traffic safety policies vary between regions. As a case in point, traffic safety stands high on the political agenda in Flanders, a region in Belgium, and many resources are spend to improve traffic safety. This is less the case in Wallonia, another region in the same country. For example, Flanders wants to lower the speed limit on interurban roads to 70 km/h, Wallonia wants to keep the 90 km/h speed limit. Moreover we see that in general the public debate emphasises increasing the probability of detection in stead of increasing the fines. This conflicts with theory (Becker 1968) prescribing that fines should be set at the highest level and that monitoring, given the costs, should be set as low as possible. We can think of two reasons why enforcement is as it is. Firstly, high fines are not a very popular measure. Politicians, who want to be re-elected, take this into account in setting their policy. This could be analysed using an electoral accountability model as developed by Baro (1973). A second reason is that there are lobby groups at work. Think, for example, of the automobile industry, vulnerable road users action groups, etc. We see for instance that the average fine for speeding and for drunk driving is positively correlated[16] with the proportion of vulnerable road users. The influence of lobby groups can be analysed using the common agency model as developed by Dixit, Grossman and Helpman (1997). We use the second approach and analyse the choice between the inspection probability and the level of the fine for speeding given a fixed expected fine. We argue that, given the expected fine, vulnerable road users opt for high fines and low probability of detection while strong road users prefer a high probability of detection and low fines. The main reason is that increasing the inspection probability is costly for society as a whole, while increasing the fine has no social costs and only affects the car drivers that violate the speed limit.

## *2.2.* Model

We assume that there are two lobby groups in society: vulnerable road users such as pedestrians, cyclists,… and 'strong' road users such as car drivers. Vulnerable road users are identical and if an accident happens, they bear all the losses. We assume that car users differ in their value of time and are risk averse in the expected fine. Both parties receive the revenue of the fines, subtracted by the enforcement cost, as a lump sum. Vulnerable road users then maximise their utility from consumption and driving. Strong road users also maximise their utility from consumption and driving and decide whether to speed or not. They will speed if the utility of speeding taking into account the expected fine is larger then the utility of complying and not paying a fine. This decision depends on their value of time. The higher the value of time, the higher the utility of speeding and the more likely they are to speed. Given the indirect utilities and the behaviour of the road users, we determine the socially optimal expected fine for an exogenously given speed limit. We find that the socially optimal expected fine is such that the marginal social benefit equals the marginal social cost of changing the expected fine.

[16] Correlation speeding-proportion vulnerable road users = 0.15. Correlation fine drunk driving-proportion vulnerable road users = 0.16. Own calculations based on FOD Economie (2002), van den Hauten ea (2005)

We then analyse the different combinations of the probability of detection and the level of the fine subject to this socially optimal expected fine. Following Dixit ea. (1997) we derive three equilibriums by maximising an objective function equal to a weighted sum of a social welfare function and the utility functions of the lobbying groups. In the benchmark case, lobbies have no influence. In the other two extreme cases the vulnerable road users get first all the weight and secondly, the strong road users get all the weight. We find that in the benchmark case the optimal probability of detection is determined by equating the marginal cost to the marginal benefit. The marginal cost consists of the increased accident cost and the increased inspection costs. The marginal benefits include the reduction in trip costs. Note that drivers will only change their speed if this generates a benefit; this is, if the decrease in the private driving cost is greater than the change, caused by the change in probability of detection, of the disutility of the fine. We cannot say whether the change in government revenue is positive or negative. If vulnerable road users get all the weight, the marginal benefits of a better monitoring are the possible increased fine revenues in which they shares but do not pay. The marginal costs of increased control are the higher monitoring cost itself and the induction in accident costs. Note that this equilibrium does not take into account any effects on the private cost. If strong road users get all the weight, the marginal benefits of more inspection are the decreased trip cost. The marginal costs of increased monitoring are the monitoring costs themselves. We do not know if the change in government revenue is a cost or a benefit. Note that this equilibrium does not take into account any effect on the accident costs and it takes into account only part of the enforcement cost and part of the government revenue. The relationship of the levels of detection and punishment preferred by the two interest groups cannot easily be compared with the socially optimal solution. Each group takes only particular elements of the complete marginal costs and benefits into account and this makes the results indefinite. However, we do argue that most likely the outcome will be such that vulnerable road users prefer a lower probability of detection and hence a higher fine then the strong road users.
This analysis is complemented with an illustration.

## *2.3.* Conclusion

If only vulnerable road users are taken into account, we find that the fine is much higher and the inspection probability lower than the social optimum. We find the reverse result when only car drivers are taken into account. The main reason for this difference is that increasing the inspection probability is costly for society as a whole while increasing the fine mainly influences the car drivers that violate the speed limit. Vulnerable road users, therefore, favour high fines and low probability of detection. Car drivers favour low fines and high probability of detection because they pay the fines and because they are risk averse. If strong road users have more influence than vulnerable road users this can explain why actual fines are lower than theoretical optimal.

More detail can be found in

Delhaye, Eef (2004), Optimal enforcement of speed violations: overview literature, working paper

Delhaye, Eef (2006), The enforcement of speeding: should fines be higher for repeated offences, ETE working paper 2006-01.

Delhaye, Eef (2006), Boetes voor snelheidsovertredingen – moeten ze hoger zijn voor recidivisten? Jaarboek Verkeersveiligheid 2006

Delhaye, Eef; Proost, Stef; Rousseau Sandra (2006), Political Economy of the Structure of Speeding Fines, working paper

# Chapter V: Cost Benefit Analysis

Traffic safety is an area of increased attention and awareness. In order to be able to conduct a good safety policy, a good evaluation of potential measures is necessary. One should consider all the benefits and costs of the measure and only implement them if their benefits are larger than their costs. In this section we consider a concrete safety measure, which is very popular in Belgium nowadays. We make a social cost-benefit analysis of rebuilding a signalised intersection into a roundabout[17]. A cost benefit analysis for other measures may be performed using the same framework.

The structure of this chapter is as follows. We first sketch the background of the problem and explain some concepts. Next we give an overview of studies which consider the effects of the rebuilding. In section 3 we present the analytical framework that we will use. Section 4 gives the actual analysis. Finally, section 5 concludes.

## 1. Introduction

In Belgium 150 people per million inhabitants die in traffic. This tragic number is magnified when we consider the corresponding larger number of serious and light injuries. Figures of the Belgian Institute for Traffic Safety (BIVV) (2001) show that in 1999 38.14 % of all injury accidents happened on junctions[18]. Because of the poor registration of traffic accidents these figures are incomplete. One estimates that the total number of accidents on junctions, including accidents with only material damage lies between 150,000 en 250,000 per year. This figure has not changed in 15 years despite the many efforts to improve safety on intersections.

There are different theoretical reasons why roundabouts may improve safety on intersections. First of all, they decrease speed, which is an important factor in the causation and severity of accidents. Secondly, they do not allow frontal accidents and eliminate left turns in front of traffic. In general, by the change of the angle, the accidents that do happen are less serious. However, the rebuilding also has other consequences: it influences the time costs, pollution and the capacity of junctions.

Given that roundabouts may improve traffic safety, but taking into account all other effects, we want to know if it is economically efficient to replace a signalised intersection by a

[17] The same analysis can be made for the rebuilding of an 'uncontrolled' intersection. This is done in Delhaye (2001).

[18] With the word junction we denote each crossing of two or more roads. Hence a junction can be an 'uncontrolled' intersection, a signalised intersection or a roundabout.

roundabout. Because of lack of data for Belgium, we rely on different studies from different countries. Note, however, that when there is data available for Belgium, the analysis is easily adapted. In section two we describe the effects we use for the analysis.

An intersection denotes every crossing of two or more roads. A ‘signalised intersection’ is an intersection where traffic lights in two or more phases rule the traffic. An ‘uncontrolled intersection’ is an intersection ruled by stop signs, priority signs or where there is right of way for traffic from the right. A roundabout is defined as an intersection for circular traffic with three features. First of all, following traffic legislation, traffic on the roundabout has the right of way. Secondly, the roundabout should have specific geometrical characteristics. There has to be a middle isle, a circular outer side, a canalising and marking of the supply roads. Thirdly, they should be signalized as roundabouts.

## 2. Consequences of rebuilding

Most studies[19] agree on the influences of rebuilding, although they can differ in the order of magnitude. They all show that the number of accidents and their severity decline. Most studies find a gain in time, although there is a difference for the main and the side road. For the other effects we only found a study by Hyden & Várhlyi (2000), which shows that the fuel use and the pollution declines. Table 1gives the exact values of the effects which we use in the analysis and the country from which the values are taken of.

[19] Akçelik R., Chung E., Besley M. (1998), Cedersund H.-°A (1995), Centre d’Etudes des Transport Urbain, Service d’Etudes Techniques des Routes et Autoroutes (1993), Hyden C., Várhelyi A. (2000), Insurance institute for highway safety (2000), Ministerie van de Vlaamse Gemeenschap (1997), Ministère Wallon de l’Equipement et des transports Service d’Etudes Techniques des Routes et Autoroutes (1998 en 1999), Technologisch Instituut-K VIV, Genootschap Verkeerskunde (1995), Van Minnen J. (1989, 1993 en 1994). For an overview of the results of the different studies we refer to Delhaye (2001).

Table 1 : The effects of rebuilding

| Effect | ‘signalised intersection’ → roundabout | Source |
|---|---|---|
| Accidents[a] | #accidents/10 mio arriving vehicles: 3.35 → 1.24 | Cetur (1993): Germany |
| | #deaths/100 accidents: 10 → 6<br>#heavily injured/100 accidents: 45 → 33<br>#lightly injured/100 accidents: 126 → 106 | Setra (1998): France |
| Time | Waiting time: 10 sec → 0<br>Geometrical time[b]:<br>Main road: 4.75 sec →12 sec<br>Side road: 14 sec →12 sec | Setra (1998): France |
| Environment | CO ↓ with 29%<br>NOx ↓ with 21%<br>Other particles: 1 to 1 relation with fuel use | Hyden &Várhelyi (2000): Sweden |
| Fuel use | ↓ with 25 % | Hyden &Várhelyi (2000): Sweden |

a: Note that the figures concerning the severity of accidents are actually the figures for ‘uncontrolled intersections’. Because we lack figures for the ‘signalised intersections’ we assume that the severity of accidents is the same for both types.
b: For the calculation of the geometrical time on an intersection we refer to IV.B.3.

This study checks if the decrease in accidents, pollution and fuel use outweighs the investment costs and the possible time loss.

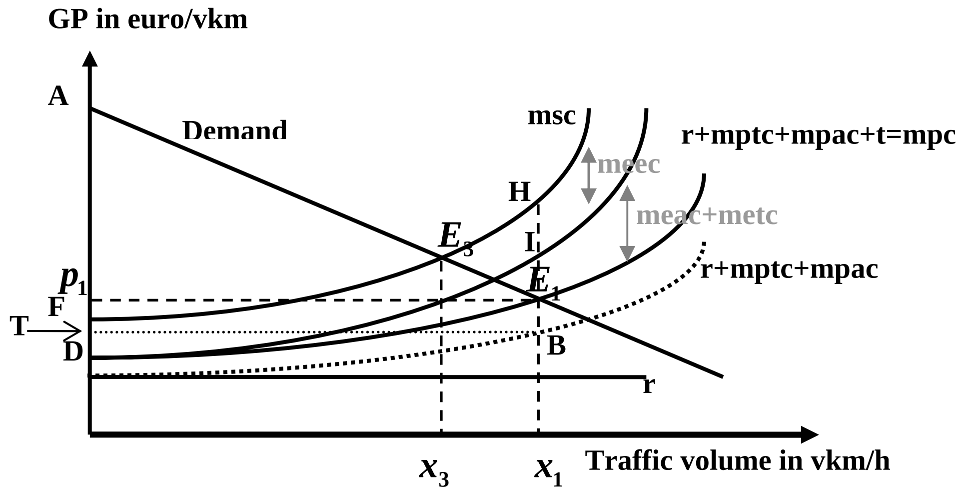
# 3. Economic Framework

The economic framework we use to determine if the rebuilding is economically efficient is based on De Borger & Proost (1997).

### (1) The current market equilibrium

For the current market equilibrium we look at the market for car trips in which one uses the intersection. Consider Figure 1.

**Figure 1: Marginal external costs in equilibrium**




First we look at the demand of vehicles for this trip. Transport is a derived demand. It is not undertaken for its own consumption value but as a mean. Demand is a function of many factors, but will obviously depend on the generalised prise (GP) of the trip. The generalised price is the sum of the resource cost, the marginal private time and accident cost and taxes. The resource cost (r) comprises the costs of the use of the car such as purchase price, insurance, maintenance and repair, etc. The marginal private time cost (mptc) equals the time spent on the journey, multiplied with the value of the time. The own accident costs (mpac) equal:

$$\sum_j \left(\text{accident risk}_j * \text{cost of accident j for the car driver}\right)$$

with j equal to the different types of accidents. The private cost of an accident j for the car user consists of the loss of joy of life and the financial costs carried by the car user himself (for example part of the medical costs). Finally the generalised costs also comprise the taxes which are connected with driving. We assume that these taxes (t) are constant.

One expects that as the generalised price raises, the demand for trips declines. Other elements which determine the demand for this trip are the generalised price of car travel on other places, of public transport, income, etc. We assume that all these remain constant.

On the supply side, we need to determine how the generalised cost depends on the traffic volume. The generalised cost also includes the resource cost and the marginal private time and accident cost. In order not to complicate the analysis we assume that the resource cost is independent of the volume. The marginal private time cost is an increasing function of the traffic volume. Indeed, the average speed of traffic flow will drop as more drivers come onto the road. The relation of the marginal private accident costs with the traffic volume is not clear cut. If there is more traffic one might expect that the number of accidents increases since the number of confrontations increases. On the other hand, the speed will decrease if there is more traffic; hence the severity of the accidents decreases. People may also drive more careful if there is more traffic.

The resource cost, the private accident costs and the private time cost together with the taxes determine the marginal private cost for the consumer (MPC). This cost consists of all monetary costs, time costs and accident cost which the traveller takes into account. On Figure 3, the current market equilibrium is $E_1$, the point at which the demand intersects the marginal private costs. The generalised price is $P_1$.

However, in a cost-benefit analysis we consider the society as a whole. Transport brings about a number of unwanted side effects such as congestion, air pollution, noise pollution, accidents... These are called negative external effects. External because the user does not take them into account. Negative because they impose a cost on society. These external costs are an increasing function of the traffic volume. The marginal costs for society (MSC) consist of the marginal private costs, the marginal external time costs, the marginal external accident costs and the marginal external environmental costs. The marginal external time costs (METC) are the extra time costs an additional road user imposes upon all other road users. The marginal external accident cost (MEAC) is the effect of an additional user on the private accident costs of the other road users. This is partly covered by the insurance if the insurance is not considered fixed and in so far as the insurance covers all accident costs. The two remaining marginal external costs are presented together on Figure 1 as MEEC. The first element is the accident costs for the rest of the society. The second element is the marginal external environmental cost. This captures pollution, noise nuisance, etc. The car user does not take these external effects into account and hence the equilibrium $E_1$ is an equilibrium with more traffic than optimal for society. In $E_1$ the marginal private willingness to pay does not equal the marginal social costs, but the marginal private costs. One can measure total welfare as the sum of the consumer surplus, the producer surplus and the net tax revenues, minus the external costs. The consumer surplus equals the difference in the willingness to pay, which is represented by the demand and real expenditures. In terms of Figure 1 the consumer surplus is represented by the area A-$P_1$-$E_1$. The producer surplus equals zero in this setting[20]. The tax revenues are simply equal to the tax per unit times quantities and are

[20] The producer surplus consists of two components. Firstly, there is the surplus for the producers of the

represented by the area $P_1$-$E_1$-B-T. The external costs D-F-H-I[21] have to be subtracted from the sum of the consumer surplus and the tax revenues.

#### (2) The replacement of a signalised intersection by a roundabout

We now show the effect of replacing a signalised intersection by a roundabout graphically. We know that the replacement of a signalised intersection caused a decrease in the accident risk and hence in the internal and external accident cost, that the fuel use and hence the resource cost and the tax revenues from transport decrease and that the environmental cost decreases. The effect on the time is not clear-cut. In other words, the generalised price to drive over the intersection decreases because of the rebuilding. This causes a decrease in the price of the total trip. Note, however, that the distance driven on the intersection is relatively small compared with the total trip. Hence the decrease of the generalised price on the intersection will not have an enormous effect on the generalised price of the trip. For we assume that the generalised price on the remainder of the road does not change[22]. In order to construct the roundabout, the government has to raise an additional tax. We assume that the income tax increases. Figure 2[23] shows the effects of replacing a signalised intersection by a roundabout.

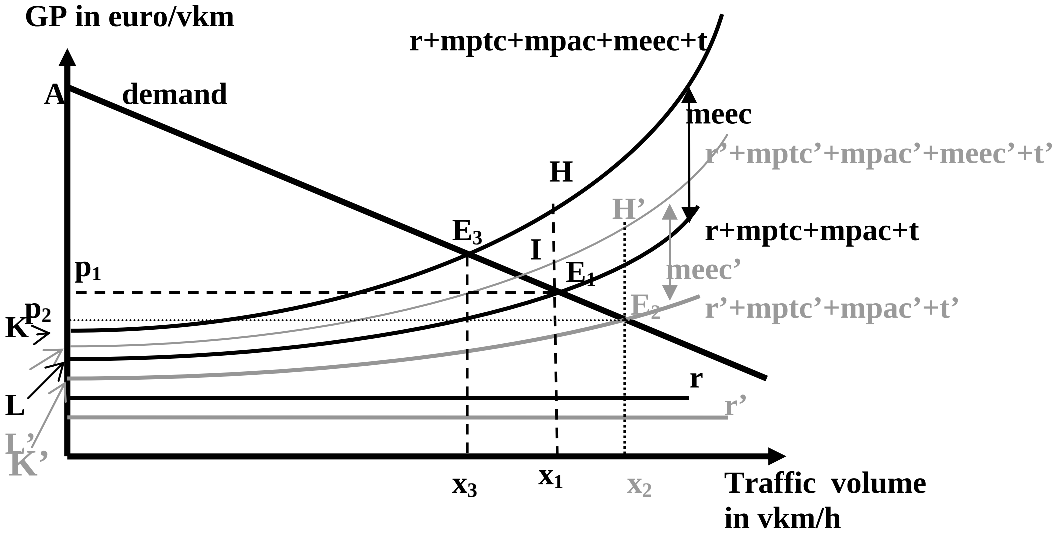
purchased goods; this is the profits of the suppliers of cars, tyres, fuel, etc. We assume perfect competition and constant production costs r per kilometre, so there is no economic profit. Hence this surplus equals zero. The second component comprises the time cost of the car user. In fact, he ‘produces’ vehicle kilometres by supplying his own time. In their dual role of consumer-producer they ‘pay’ their own time cost. However, because he pays exactly the average time cost, this second surplus also equals zero.

[21] The external costs equal D-F-H-$E_1$. However if we would subtract this, we would be double counting. For in our calculation of the consumer surplus we already take into account the total cost of time. This total cost of time comprises the private and the external cost of time. Hence we already take into account the external time costs. This is the same for part of the accident costs. Hence we can only subtract the area D-F-H-I.

[22] We assume that the additional users do not influence the time cost and the accident risk on the remainder of the road. This assumption is made because of practical reasons. Note that in reality a change on one point can affect the remainder of the stretch. It is possible that traffic is smoother on the roundabout but less smooth somewhere else in the trip. This means that we overestimate the benefits of the rebuilding on time, environment and fuel use. The effect on accidents is not clear. The precise effects depend on the network and taking them into account would complicate the analysis too much.

[23] Note that this figure is slightly different from Figure 1. For reasons of clarity we did not take up the METC and the MEAC.

**Figure 2: The effect of replacing a signalised intersection by a roundabout**




The generalised price decreases from $P_1$ to $P_2$. As a consequence the demand will increase[24] from $X_1$ to $X_2$.

The net effect on welfare can be seen by calculating the difference in total welfare in the two equilibriums:

$$\text{net benefit/cost} = \Delta CS+\Delta PS+(1+\lambda)\Delta TR+\Delta EXT$$

The first element equals the change in consumer surplus and is represented in Figure 2 by the area $P_1$-$P_2$-$E_1$-$E_2$. In other words, we consider the difference between the two alternatives in resource cost, time cost and private accident cost for existing as well as for new users. The difference in producer surplus equals zero in this exercise, given that the producer surplus before and after equal zero. The third element, which is not represented in Figure 2, has to do with the fact that the construction of roundabouts happens with tax revenue (TR). We have to take into account the investment itself and possibly the difference in maintenance costs. Moreover because of the effect on fuel use and the increase in demand there will also be an effect on the tax revenues from transport. These taxes will cost more to society than the amount needed since levying taxes causes distortions. This is why we multiply with $(1+\lambda)$, the marginal cost of public funds. The fourth element is the change in external costs for the society. In Figure 2 this is represented by H-$E_1$-L-K minus H'-$E_2$-L'-K'.

If this sum is greater than zero, we have a net benefit and it is economically efficient to construct roundabouts. If the sum is negative, it is better to use the money for something else.

[24] Note that for reasons of clarity we exaggerated the magnitude of the shifts.

# 4. The replacement of a signalised intersection by a roundabout

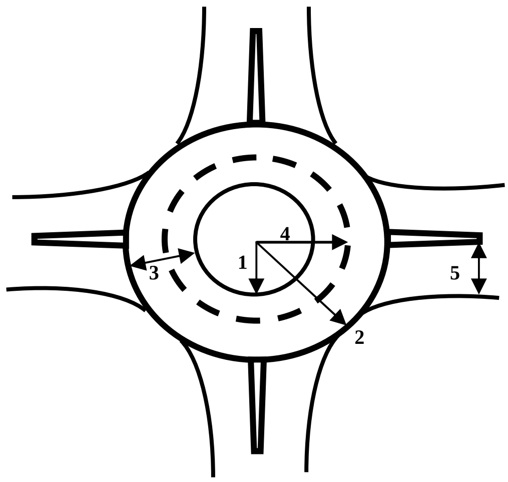
In this paragraph we discuss the actual cost-benefit analysis. We consider the effects for one year. All figures are in euro (2000)[25]. We start with a number of assumptions. Next, we give the calculation of the generalised price and the change in demand. We conclude with the actual cost-benefit analysis.

#### (1) Cost-Benefit analysis: assumptions

In order to be able to perform this cost-benefit analysis we have to make a number of assumptions.

Firstly, we consider a roundabout with four branches and assume measures such as given in Figure 3.

**Figure 3: Design of the assumed roundabout**




With
1 = Bi, the radius of the inner circle = 10.5 meter
2 = Bu, the radius of the outer circle = 16 meter
3 = the width of the road = 5.5 meter
4 = the radius of the circle, which divides the road into half = 13.25 meter
5 = R, the width of the road of the branches = 3 meter

Secondly, we assume that traffic on the side road equals 30% of the traffic on the main road. We also assume that half of the cars drive straight ahead and that one fourth turns to the right and one fourth turns to the left.

Thirdly, we assume[26] that during the peak hours on average 750 car-units (CU) approach the roundabout/intersection from the main road. This means that 23.1% of these 750 CU[27], this is

[25] European Commission (2000), NBB (2001).

[26] Ministère Wallon de l’Equipement et des transports, direction générale des autoroutes et des routes (1992).

[27] Remember the second assumption: the traffic on the side roads equals 30 % of the traffic on the main road.

173.25 CU, approach the intersection from the side roads. This gives an average of 461.63 CU per branch. We assume that the peak counts for 12% of the daily traffic. This leads to 3,846.88 CU/day/branch. We multiply with 4 and assume that yearly traffic equals 300 times the daily traffic. This leads to 4,616,250 CU per year per intersection before the reconstruction.

Furthermore we assume an occupation rate of 1.2 persons on average per vehicle.

Because environmental effects differ between gasoline and diesel cars we categorize cars according to their fuel type. In Belgium the share of gasoline cars is 59.4 %, the share of diesel cars equals 40.6 %. We assume that these shares are also reflected in the traffic on the intersection.

For the fuel prices we use the average fuel prices for the fiscal year 2000 as calculated by the price service of the Ministry of Economic Business (2001).

For the sake of simplicity we assume that the new users did not travel before[28]. If among the new users some people took a different road before, the rebuilding also has an effect on the other roads.

Finally, note that in our calculation we do not take everything into account. We do not take into account the loss in time, drivers face during the rebuilding. Secondly, note that studies show that in the months close after the rebuilding, the number of accidents increases. People seem to adapt rather slowly to changed conditions. We assume that the accident risk is constant over time. Thirdly, we do not consider bicyclists and pedestrians. The study of Van Minnen (1993) shows that the number of accidents with bicyclists and pedestrians decrease, but not as much as the decrease for the occupants of the vehicles. Factors one and two make that we overestimate the benefits of the rebuilding. The third factor leads to an underestimation.

#### (2) Change in demand

From Figure 2 it was clear that the generalised price decreases because of the rebuilding. In order to know the change in demand, we need to calculate the change in generalised price. The generalized price per trip equals (the number of km on the intersection*generalised price per km on the intersection) + (the number of km on the remainder of the trip*generalised price per km on the rest of the road).

[28] For a change of this assumption we refer to the sensitivity analysis.

Km per vehicle

We assume[29] that vehicles drive in the middle of the road and hence drive on an imaginary circle with a radius of 13.25 metre. The circumference of the circle then equals 83.25 metre. We assume that on average half of this distance is covered[30], this is 41.63 metre. For the sake of simplicity we assume that the covered distance on the crossing is on average the same as on the roundabout.

The average trip length in Belgium is 13 kilometres. The number of kilometres on the remainder of the road then equals 12.96 kilometres.

Fuel and vehicle costs per kilometre

The prices and the fuel consumption differ between gasoline and petrol cars. This is why we first calculate the fuel prices (net of taxes) per kilometre by multiplying the price and the consumption. Next, we multiply with the respective shares to obtain one weighted price. We do this for the signalised intersection, the roundabout and the remainder of the road. Note that the reconstruction affects the fuel consumption. Because one has to stop and start less, the average fuel consumption declines with on average 25% (Hyden & Várhlyi, 2000). We assume that the decline is the same for gasoline and diesel cars. We obtain a fuel price of 0.03 euro/km on the signalised intersection and on the remainder of the road[31] and 0.02 euro/km on the roundabout.

For the vehicle costs per year we use data from De Borger & Proost (1997). These costs consist of the annuity of the purchase costs, the traffic tax, the insurance, the radio taxes, repairs, battery costs, the costs of tyres and oil. We remove the taxes[32] and find, using the respective shares of gasoline and diesel cars, a weighted average vehicle cost per km of 0.21 euro. The replacement of a signalised intersection by a roundabout does not affect the vehicle costs.

Time cost per vehicle

We need to distinguish waiting time from geometrical time. Waiting time is for example the time that people wait for the red lights, the time that one is waiting in the row and the time needed to turn left. In other words it is the time loss caused by traffic or by lights. A study of Setra (1998) shows that the average waiting time on a ‘controlled’ crossing is around 10 seconds. On a roundabout the waiting time is the time that one has to wait before one can ride

[29] See Figure 5.

[30] See the assumptions on the shares of the directions: 1/2, 1/4, 1/4.

[31] Note that the price on the road and the signalised intersection are equal because of rounding off.

[32] We assume an average tax rate of 21 %.

up the roundabout. We assume that the maximum capacity of the roundabout is not reached and hence that the waiting time is around zero seconds[33]. Note that this is not a realistic assumption in peak traffic. Geometrical time is the time needed to cross the signalised intersection/roundabout. For the signalised intersection we need to distinguish the main from the side roads. A car on the main road will have a higher probability to drive straight ahead and hence will be faster on his destination than a car on the side road. For the calculation of the geometrical time we use the data from Setra (1998). After adjusting for the different shares of driving direction (1/2, 1/4, 1/4) we obtain a weighted average geometrical time on the main road of 4.75 seconds and 14 seconds on the side roads. Because we assume that traffic on the side road equals 30% of traffic on main roads, we multiply the geometrical time on the side roads (main road) with 23.1 % (76.9 %). The average geometrical time on a roundabout equals 12 seconds for passenger vehicles. The total time needed to cross the signalised intersection equals 10 sec + (0.231*14 sec +0.769*4.75 sec) or 16.89 seconds. The total time needed to cross the roundabout equals the geometrical time, or 12 seconds, since we assume that there is not waiting time. We assume that on the remainder of the road, the average speed equals 31.1 km/h[34]. Hence one needs 1500 seconds to cover the remaining 12.96 kilometres.

In order to obtain the time cost per vehicle we need to multiply these values with the value of time per vehicle. We use the results of Gunn et al (1997) to calculate the value of time per vehicle. They calculate the value of time for different trip purposes using ‘stated preferences’. We multiply these values with the respective shares of the trip purposes[35] to obtain an average money value per hour. We get an average value per hour of 9.29 euro for peak travel and 8.58 euro for off-peak travel. If we assume that the peak counts for 12% of all traffic and that, on average, the occupancy rate per car is 1.2 persons, we obtain an average value of time of 10.44 euro/vehicle/hour or 0.0029 euro/vehicle/second. The time costs that we then obtain are expressed in Table 2.

[33] This assumption is not very strict. One can also consider this as a normalization. Important for the analysis is that the difference in waiting time equals 10 seconds.
[34] BIVV (2001).
[35] Stratec (1992).

Table 2: Time cost per vehicle

| | Signalised intersection | Roundabout | Remainder of the trip |
|---|---|---|---|
| time(sec/vehicle) | 16.89 | 12 | 1,500 |
| value of time (€ /sec) | 0.0029 | 0.0029 | 0.0029 |
| **Time cost/vehicle (€ /vehicle)** | **0.05** | **0.03** | **4.35** |

Source: Setra (1998), own calculations.

Because of the rebuilding the time needed to cross the intersection declines, and hence the time cost per vehicle declines.

Marginal private accident cost per vehicle

Accident costs can be divided into costs, which are already expressed in monetary terms and those, which are not. In the first group we find, among others, damages to property and vehicles, medical expenses, costs for the ambulance and the police. Somewhat more reluctant we can say that also the net loss in production, caused by the fact that the victim cannot work anymore, belongs to this group. For we can approximate this by his gross wages minus his consumption. However it is much more difficult to value pain, discomfort and suffering caused by injury and death. We note that in deciding whether to participate in traffic, the user partly takes into account that he might have an accident in which he can be killed, injured and/or have material damage. Hence, part of the accident cost is internalised and is consequently considered as a private cost. In Figure 2 this was denoted by mpac. However, there are also external costs, such as the influence an additional road user has on the accident risks for the other users. Moreover, in case of an accident not all costs are paid by the victim. Part of the accident costs are paid by society.

We define the marginal private accident cost per vehicle as in paragraph three.

Note that we only take into account the private costs, in other words the costs which people take into account. We approximate these costs by the ‘human costs’ of Schwab (1995). These values are obtained by using the ‘stated preferences’ method. The other costs (rehabilitation costs, loss in production, medical and administrative costs) are considered external. The value of an accident with serious injuries is approximated by accidents which cause disability. Given the definition of an accident with serious injuries this figure will be an overestimation of the value of being seriously injured.

Table 3: Valuation of accident

| Accident costs | Fatal accident | If handicap | Light injury |
|---|---|---|---|
| Human costs (€) | 1,099,103 | 899,416 | 95,311 |
| Total other costs (€) | 1,004,861 | 459,413 | 5,717 |
| **Total costs (€)** | **2,103,964** | **1,358,830** | **101,028** |

Source: Schwab (1995).

For the calculation of the accident risks we use German and French data (Table 1). We combine the own willingness to pay with the accident risk and obtain the marginal private accident cost as expressed in Table 4.

Table 4: Marginal private accident cost

| | Signalised intersection | | | Roundabout | | | Remainder of Trip[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Risk #victims/ vehicle | WTP €/victim | Mpac €/ vehicle | Risk #victims/ vehicle | WTP €/victim | Mpac €/ vehicle | Risk #victims/ vehicle | WTP €/victim | Mpac €/ vehicle |
| Fatal | 3.35E-08 | 1,099,103 | 0.04 | 7.44E-09 | 1,099,103 | 0.01 | 2.19E-07 | 1,099,103 | 0.24 |
| Heavily injured | 1.51E-07 | 899,426 | 0.14 | 4.09E-08 | 899,426 | 0.04 | 1.24E-06 | 899,426 | 1.11 |
| Lightly injured | 4.22E-07 | 95,311 | 0.04 | 1.31E-07 | 95,311 | 0.01 | 2.22E-05 | 95,311 | 2.11 |
| **Sum** | | | **0.21** | | | **0.06** | | | **3.47** |

a: the accident risk on the remainder of the trip is the accident risk over 12.96 km.

Source: Schwab (1995), own calculations.

From Table 4 it is clear that the private accident cost is much lower on the roundabout.

Taxes.

We assume a tax of 21 % on the resource cost and obtain a tax cost of 0.04 euro per km. For the fuel taxes we multiply the fuel consumption with the taxes on gasoline and diesel. Next we calculate the weighted average taking into account the fuel shares and obtain a fuel tax of 0.05 euro/km on the signalised intersection, 0.03 euro/km on the roundabout and 0.05 euro/km on the remainder of the trip.

The generalised price and the new demand.

Table 5: Generalised price per vehicle

| | Signalised intersection | Roundabout | Road |
|---|---|---|---|
| Resource cost (€/vehicle) | 0.007 | 0.007 | 2.23 |
| Time cost (€/vehicle) | 0.05 | 0.03 | 4.35 |
| Mpac (€/vehicle) | 0.21 | 0.06 | 3.47 |
| Taxes (€/vehicle) | 0.003 | 0.003 | 1.07 |
| **Generalised price (€/vehicle)** | **0.27** | **0.10** | **11.49** |

Source: own calculations.

Table 5 summarizes the impact on the generalized price. We see that the rebuilding of the intersection more than halves the generalised price. The most important factor is the decrease in mpac. The generalised price of the trip equals 11.76 before and 11.59 euro after the rebuilding. Given a price elasticity of –0.5 we can calculate the increase in demand. The demand for the trip will increase with 33.371 car-units and in the situation after the rebuilding there will be 4.649.621 car-units driving on the roundabout[36].

#### (3) Cost-benefit analysis for one year

Consumer surplus

We denoted the change in consumer surplus on Figure 2 by the area $(P_1-P_2)*X_1$ for the existing users and the triangle $(P_1-P_2)*(X_2-X_1)/2$ for the new users. Using $X_1$, $X_2$, $P_1$ and $P_2$ we calculate the two areas. We obtain a gain in consumer surplus of 781,141.69 euro for the existing users and 2,837.94 euro for the new users. This consumer surplus consists of the gains in time, in private accident cost and in fuel use.

Government

a. Taxes

We assumed that the resource cost was unaffected by the rebuilding. Hence the tax revenues on the resource cost stay constant for the existing users. However, the new users make that the revenues rise with 15,672.50 euro.

With respect to the fuel taxes we multiply the difference in use for the existing users with the taxes and with $X_1$. We obtain a loss of 2,211.53 euro. However, there are also new users. They generate an additional revenue of 35,079.93 euro.

Hence the rebuilding raises the tax revenues of the state with 48,540.89 euro.

b. Investment cost and maintenance

[36] For the exercise in which the number of car-units stays constant we refer to the sensitivity analysis.

The exact cost of rebuilding are hard to calculate since the budgets used for constructing roundabouts often also incorporate other items, such as the reconstruction of roads near the roundabout. Hence the cost of a roundabout varies between 123,946.76 euro and 1,239,467.62 euro. We only consider the costs of rebuilding a signalised intersection into a roundabout. We assume that because of the limited diameter of modern roundabouts there are no expropriations. We use the costs stated by the Flemish Community (1997). The costs of rebuilding a signalised intersection into a roundabout then equals 467,136 euro. However a roundabout has its use for more than one year, hence we only have to take into account the cost for one year. Assuming a life expectancy of 10 years and a discount rate of 5 % we obtain an annuity of –60,456 euro.

For calculating the costs of maintenance we take the difference in area and multiply this with the cost of maintenance. For the roundabout we also have to take into account the cost of maintenance of the inner circle. However, an advantage of a roundabout is that there are no lights which need maintenance or which can get defect. For the difference in maintenance we consider the difference in square kilometres for the 'black' (the road), the 'green' (the plants on the middle island) and the electric appliances. For the last element we only consider the fact that a roundabout does not have three-coloured lights. We do not consider the difference in yellow cones and traffic signs and assume that these costs are equal. For the maintenance of the green we multiply the area of the inner island with the cost of mowing the lawn[37]. We assume that this is done twice a year. We obtain a cost of 429.49 euro. For the difference in maintenance of the road we multiply the difference in area between the signalised intersection and the roundabout with the average cost of maintenance[38]. We obtain a cost of 90.84 euro. For the maintenance of the traffic lights we consider the energy cost per year. This equals 1,735 euro. In sum, we obtain a profit in maintenance of 1,214.67 euro. This is caused by the high operating costs of traffic lights.

Note that the investment and the maintenance are financed by taxes on labour, of which the marginal cost of public funds equals 1.2.

<u>External costs</u>

a. Accidents

(1) Existing users

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[37] The cost of mowing the lawn equals 0.62 euro/m². Source: Flemish Community: P. De Backer (2001), personal communication.

[38] The cost of maintenance of the road surface equals 0,16 euro/m². Source: Flemish Community: P. De Backer (2001), personal communication.

Given the decrease in accident risk, the roundabout decreases the number of traffic accidents. We see a decline for all types of accidents. Hence the roundabout causes a benefit for society. We have to value the difference in accident risk using the costs for society. We use the values obtained by Schwab (1995). We multiply the difference in accident risk with their respective monetary values and obtain a monetary value per vehicle. Next, we multiply with the existing number of car-vehicles.

Table 6: Effect on the external accident cost for the existing users

| | Difference in acc risk (per vehicle) | External cost (€/vehicle) | Monetary (€) |
|---|---|---|---|
| Fatal | 2.61E-08 | 1,004,861 | 0.0262 |
| Heavily injured | 1.10E-07 | 459,413 | 0.0505 |
| Lightly injured | 2.91E-07 | 5,717 | $1.6636*10^{-3}$ |
| Total/vehicle | | | 0.07836 |
| **Total/intersection** | | | **361,478.74** |

Source: Schwab N., Soguel N. (1995), NBB (2001), European commission (2000), own calculations.

As is evident from Table 6 the effect of rebuilding on accident for existing car users causes a monetary benefit of 361,478.74 euro. Note that the effect on the number of heavily injured dominates. The relative high valuation and the high occurrence of accidents with heavily injured play an important role in this. Note, however, that there are more single-vehicle accidents and accidents with only material damage on a roundabout. Given that these are less reported, there will be an underestimation of the number of accidents and the number of light injuries on a roundabout. Hence we overestimate the benefits of the roundabout. However, we cannot determine the magnitude of the fault.

(2) New users

The new users take into account the new accident risk. However they do not take into account the increased accident risk they cause on the rest of society. Hence we need the multiply the number of new road users with the new accident risk and with the costs for society. The results are expressed in Table 7.

Table 7: Effect on the external accident costs for the new users

| | Risk trip/vehicle (roundabout+road) | External cost (€/vehicle) | Monetary (€) |
|---|---|---|---|
| Fatal | 2.26E-07 | 1,004,861 | 0.23 |
| Heavily injured | 1.28E-06 | 459,413 | 0.59 |
| Lightly injured | 2.23E-05 | 5,717 | 0.13 |
| Total/vehicle | | | 0.94 |
| **Total/intersection** | | | **31,466.89** |

Source: Schwab (1995), Setra (1998), Cetur (1993), own calculations.

Because of the new users the accident benefit of roundabouts decreases. If we subtract the costs of the new users from the benefit for the existing users we obtain a net benefit of 330,012.85 euro.

b. Environmental effects

According to Table 1 the rebuilding of a signalised intersection into a roundabout also affects the discharge and hence the environment and our health. The rebuilding increased the discharges on the main road but decreased them on the side road. On average the discharge of CO of existing road users decreases with 29 % and the discharge of NOx with 21 %[39]. There will also be an effect on the other pollutants, but we do not have data for them. We assume that there is also a decrease in those pollutants, proportional to the decrease in fuel use. For there exist a 1 to 1 relationship between discharge and fuel use, given the same technology for many of these pollutants.

(1) Valuation of air pollution

We use the values stated by Proost & Van Dender (1998), based on Extern-E. Because the discharge is different for diesel and gasoline cars we need to consider them separately. Note however that there is also a difference for large and small vehicles and between peak and off-peak. We do not take this into account.

(2) Existing users

We know the discharge per kilometre, but we only need the discharge over the distance driven on the signalised intersection/roundabout for the existing users. We assume as before that the average distance on the junction and roundabout are the same and equal to 41.63 meter. After calculating the discharge on the intersection, we consider the decline in discharge and multiply this with the respective monetary valuations. We then obtain a monetary value per

[39] Hyden C., Várhelyi A. (2000).

vehicle, which we multiply with the number of victims. We do this for both fuel types. Table 8 gives the results for the existing users.

Table 8: Effect on the environmental costs for the existing users

| | NOx | CO | CO2 | VOC | PM | Sox | Total |
|---|---|---|---|---|---|---|---|
| Gasoline (€) | 26.67 | 0.22 | 185.80 | 5.09 | 94.32 | 10.37 | 284.85 |
| Diesel (€) | 50.70 | 0.04 | 104.76 | 2.54 | 701.1 | 36.74 | 791.38 |
| **Total contribution (€)** | | | | | | | **1,076.23** |

Source: own calculations.

(3) New users

However there are also new users and they cause additional pollution. For them we have to differentiate the road from the intersection. The calculations are as before. Table 9 summarizes the additional environmental costs.

Table 9: Effect on the environmental costs for the new users.

| | Roundabout | Road | Total (€) |
|---|---|---|---|
| Gasoline (€) | -6.31 | -2,604.34 | -2,610.65 |
| Diesel (€) | -17.41 | -7,200.58 | -7,217.99 |
| **Total contribution (€)** | | | **-9,828.64** |

Source: own calculations.

Note that the new users cause an environmental cost of 9,828.64 euro. Combined with the benefit for the existing users we get a net loss of -8,752.41 euro.

<u>Total monetary value of replacing a signalised intersection by a roundabout</u>

Table 10 summarizes all costs and benefits for one year. By making the sum we obtain the final cost or benefit of the rebuilding.

Table 10: Total monetary effect of replacing a signalised intersection by a roundabout per year

| | | |
|---|---|---|
| Consumer surplus (€) | | 787,980 |
| The Government (€) | Tax revenues | 48,541 |
| | Investment costs | -60,456 |
| | Difference in maintenance | 1,215 |
| | MCPF[40] | -2,140 |
| External costs (€) | Accidents | 330,013 |
| | Environment | -8,752 |
| **Total (€)** | | **1,096,400** |

Source: own calculations.

Notice that the rebuilding of a 'controlled' junction into a roundabout causes a social benefit. The largest contribution is attributed to the positive effects on the external accident cost and the consumer surplus. Within the consumer surplus the private accident cost is the most important element.

Sensitivity analysis

In order to make this analysis we made a lot of assumptions. We perform a sensitivity analysis to see how robust the results are. Table 11 gives the final total benefits for society of the rebuilding given a number of changes in the base assumptions.

Table 11: Sensitivity analysis

| Change in assumption | Total welfare |
|---|---|
| Marginal external accident cost = 0 | 766,387 |
| Own willingness to pay = 0 | 360,376 |
| MEAC = 0 and WTP = 0 | 2,923 |
| Value time = 0 | 1,041,054 |
| Investment cost 16.11291 higher | 0 |
| If all traffic on side roads | 1,194,689 |
| If all traffic on main roads | 1,066,889 |
| If only gasoline cars | 1,111,959 |
| If only diesel cars | 1,072,153 |
| If no change in demand | 1,073,953 |
| If all new users come from different roads | 1,079,393 |

Source: own calculations

[40] We already mentioned that it costs more than 1 euro to collect 1 euro in taxes. There is an additional cost, $\lambda$ . Because of the rebuilding there is an investment cost, a difference in maintenance and a loss in tax revenues from fuels. In total there is a loss of 10,700 euro. However this loss has an additional cost of 2,140 euro.

Note that we obtain a benefit for society in each of the cases. Even if the meac and the willingness to pay equal zero we obtain a benefit, in other words, even if the accident risk stays constant, we still obtain a benefit. Also notice that the most important effects on the benefit are due to changes in assumptions with respect to accidents. This points to the importance of the consequences on accident risk because of the rebuilding. If the investment cost is 16 times higher, social welfare does not change due to the rebuilding. If the cost is smaller than 16 times the investment cost, ceteribus paribus, we obtain a benefit; if the cost is higher we obtain a loss.

Notice that when the demand for transport stays constant the result does not change drastically. With respect to the original analysis, the gain in consumer surplus is lower, the tax revenues become negative and the MCPF becomes more negative. On the other hand we find that the gain in accidents and environment is larger. With respect to the environment, we now even obtain a benefit in stead of a cost.

If we assume that the ‘new’ users are people which change stretch this does not change the result dramatically. We assume that the conditions on the old stretch are similar to the conditions on the new stretch before the rebuilding takes place. Because of this assumption the changes in time, accident risk, environment and fuel use are the same as for the existing users. Hence we can sum the existing and the ‘new’ users and multiply with the difference in time, accidents, etc. The tax revenues now become negative and the MCPF becomes more negative. On the other hand, the gain in accidents and environment is larger. On the old stretch the situation for the remaining users will also improve. Because there are less users there, traffic will be smoother and there can be a gain in time, fuel use and environment. The effect on accidents is not clear cut. The effect on the users of the other stretch is practically not quantifiable, but will most likely contribute to a larger benefit of the rebuilding.

# 5. Conclusion

We conclude that, because of the smoother and safer traffic, the roundabout is preferred to the signalised intersection. The sensitivity analysis showed that this result is fairly robust. However we did not take into account a number of things. We did not take into account the time losses, which occur during the rebuilding. Secondly, we kept the number of accidents constant over time and thirdly, we did not consider pedestrians and bicyclists. Factors one and two make that we overestimate the benefits of the roundabout. The third factor most probably leads to an underestimation.

This study also shows that there is need for good data or at least a study on the comparability and transferability of data between countries.
Finally we would like to note that this framework can also be used to study the transformation of an ‘uncontrolled ‘junction into a roundabout and for small and large roundabouts. However the conclusion will not necessarily be the same. For the effects of the rebuilding on accident, time and environment and the investment cost will differ. Delhaye (2001) found that the rebuilding of an ‘uncontrolled’ junction into a roundabout, given the assumptions, led to a cost for society.

More information can be found in
Delhaye E. (2002), Kosten-Baten analyse van het vervangen van een geregeld kruispunt door een rotonde.

# Chapter VI : Policy Conclusions

The main goal of this research was to develop a more economic approach to traffic safety. Based on this research we make the following policy conclusions.

Given that the budget is limited, a good evaluation of measures is necessary in order to be able to conduct a good safety policy. If one makes a social cost-benefit analysis of a safety measure one should take into account all effects. This is, one should not only consider the safety effect, but also the effects of mobility, pollution, tax revenue,… Our research showed that making a cost-benefit analysis of an infrastructural or technical measure is quite straightforward. The example we provide can be used as a structure for other cost-benefit analyses. However, despite the relatively ease of making such an analysis; it is not common practice on any governmental level. The lack of good data probably plays a role in this.

By making an overview of the existing policy, we immediately noted that the competences with respect to traffic safety are widely scattered. In our view, this has two main consequences. Firstly, it is hard to learn what the actual policy is and what the budget for traffic safety is. Secondly, a coherent traffic safety policy is difficult to accomplish.

Our research with respect to liability rules showed firstly that the existing strict liability rule for accidents involving a car and a vulnerable road user is not optimal. Secondly, we showed that, in general, in order to improve traffic safety it is better to use regulation than liability. Thirdly, we proofed that in analysis the effects of one instrument, one should take into account the interaction effects with other instrument in use. The illustration on the joint use of liability rules, regulation and a km tax favoured the introduction of a km tax for all types of roads and suggests that it might be optimal to abolish the speed limit on highways, as is the case on some roads in Germany.

The research on the enforcement of speed limits first showed that it is a good idea to have higher fines for repeated offenders. This is, in theory, currently the case in Belgium. However, courts often lack the data to know if the offender has a record or not. The analysis can be used to calculate whether the costs of a centralised database are justified or not. The result can also been seen as an argument for introducing a demerit point system. This in fact punishes repeated offenders more harshly and is more flexible than the current fining system. This

flexibility can make that the system provides better signals with respect to the type of the drivers. The illustration showed that if one only takes into account the effects on traffic safety, it would be optimal to decrease the speed limit from 90 km/h to 70 km/h. However, a good cost-benefit analysis of this measure would imply taking into account all effects, this is, the safety effects and the effects on mobility, environment, noise, etc.
Secondly, we showed that traffic safety policy might be influenced by lobby groups. This might explain why the current enforcement system is as it is. It is important that policy makers are aware of this influence. It can make that some theoretical optimal (combinations of) instruments are not feasible in practice.

All illustrations and applications showed one thing very clearly. This is the lack of good data. It is a well known problem that we are far behind other European countries in publishing the data with respect to traffic fatalities. It is impossible to get a good idea of the current budget for traffic safety. Also, with respect to enforcement, no one seems to have any idea of the current probabilities of detection. The effects of different concrete safety measures are not known. Hence to make a cost-benefit analysis, one has to rely on foreign data and assumptions. These are only a few examples. This shows that a better data collection is needed.

We end this section by stressing that more research on the social aspect of traffic safety is worthwhile. For example, cyclist and pedestrians have on average a lower income, but are more vulnerable in traffic. Moreover, a uniform fine punishes the ‘poor’ more. Hence, it might be optimal to have income dependent fines.

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