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EFFECTS OF SWEDISH TRAFFIC SAFETY RESEARCH 1971 - 2004

Main report

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Effects of Swedish traffic safety research 1971 - 2004

Main report

by

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VINNOVA´s foreword

Traffic accidents are a major social problem. Costs for killed and injured in 2005 have been estimated to exceed 29 billions Swedish crowns. To this number should be added considerable human pain.

However, the ongoing development as regards traffic safety is positive. During the period 1970 – 2004, the number of killed per year has been reduced to one third, from 1307 to 440 per year, despite the fact that the amount of traffic has more than doubled in this period. This positive development includes unprotected road-users as well as drivers and passengers in vehicles. Furthermore, there are no signs that this positive development should not continue.

The present impact analysis demonstrates that research on traffic safety has had great importance for the increase of traffic safety. At the same time, it has formed the basis for considerable commercial success within the automotive industry.

To our knowledge, this is the first time that an analysis of an entire research field over a period as long as 33 years has been concluded, allowing an overview of the full effects of the research.

The following questions were asked at the start of the analysis: What effects and benefits society, companies and university research has been generated by the contributions made by VINNOVA and it's predecessors KFB, TFB and TFD, as well as the Programme Council for Vehicle Research (PFF)? And what mechanisms have been important to achieve these effects?

A first step of the analysis was to gain an overview of the research that has taken place, ref. Svensk trafiksäkerhetsforskning i tätposition (VA 2005:08), author Anders Englund (in Swedish only).

The analysis has been performed by a team at the Norwegian Institute of Transport Economics (TÖI), composed by Marika Kolbenstvedt project leader, Rune Elvik and Beate Elvebakk. The team was complemented by professor Arild Hervik and Lasse Braein at Molde University College, both recognised evaluators in Norway. Knut Sandberg Eriksen, Rolf Hagman and Fridulv Sagberg at TÖI have contributed with case studies. The analysis draws partly from VINNOVA's analysis Impacts of Neck Injury Research at Chalmers University of Technology (VA 2005:05), also performed by TÖI and Molde University College.

The analysis has been supported by an experienced reference group including Anders Englund, Christer Hydén Lund Institute of Technology, Claes Tingvall Swedish Road Administration, Hans Norin Volvo Car Corporation, Hans-Erik Pettersson Swedish National Road and Transport

Research Institute, Maria Krafft/Anders Kullgren insurance company Folksam, Per Lövsund/ Mats Svensson Chalmers University of Technology, Yngve Håland Autoliv, plus Joakim Tiséus and Ove Pettersson at VINNOVA. The group has contributed with deep understanding of Swedish traffic safety research, with viewpoints and enthused discussion.

VINNOVA gives considerable importance to analyses that describe the impact that results from our funding. Viewpoints on the present analyses are welcomed - please contact Torbjörn Winqvist at our Strategy Development Division, who has served as VINNOVA's project leader.

VINNOVA in September 2007

Per Eriksson
Director General

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Summary

Traffic accidents are a major social problem, estimated by WHO to become the world's third largest health problem by 2020. On a global basis, some 1 - 1.5 million people are killed in traffic accidents annually. To this should be added all those who are injured. In Sweden alone, the total socio-economic costs of traffic accidents each year are around 30 billion SEK (table S.1). Thus there are great human and socio-economic benefits to be gained from increased traffic safety.

Table S.1: Numbers killed and injured *) in Swedish traffic accidents in 2005 together with an estimate of the costs based on SIKA's evaluation (2001-prices). In million SEK

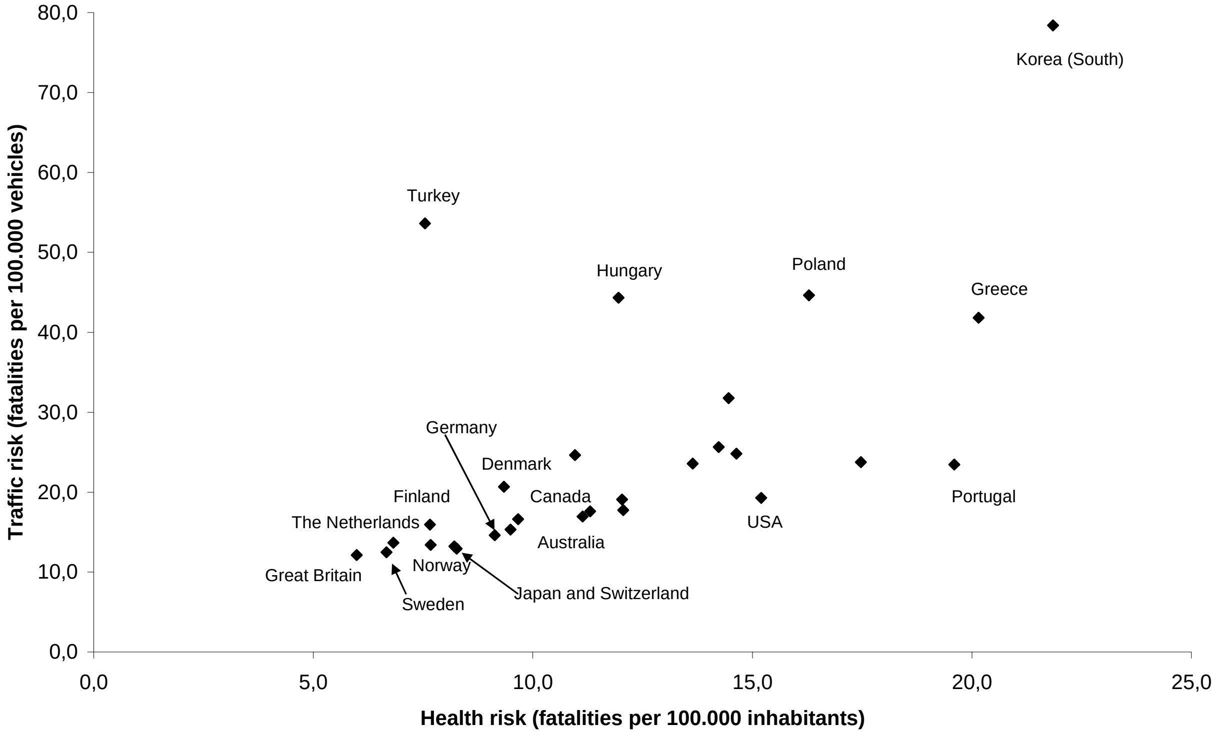
Degree of injury	Annual total for 2005	Cost per injury	Social cost
Killed	440	17.50	7 700
Seriously injured	4 400	3.12	13 700
Minor injuries	44 000	0.18	7 900
Total			**29 300**

**) The statistics for injuries are not complete. According to SIKA's accident statistics, the reporting level is 59 % for serious injuries and 32 % for minor injuries. This gives a ratio between fatalities, serious injuries and minor injuries of 1:15:160 respectively. The report uses the ratios of 1:10:100 in order not to overestimate the numbers of people injured.*

There are major differences between countries with regard to risk in traffic. The level of risk is affected by a country's economy, degree of motorisation, knowledge of effective safety measures and the resources available for preventing and reducing injuries.

Traffic safety in Sweden is very good compared both to what it was in 1970 and to what it is today in other countries with a high level of motorisation. Today Sweden is one of the world's leading countries within traffic safety (figure S.1). Sweden has succeeded in reducing the numbers killed in traffic from 1307 in 1970 to 440 in 2005, despite the fact that the amount of traffic has more than doubled in this period.

Figure S.1: Health risk (fatalities per 100,000 inhabitants) and traffic risk (fatalities per 100,000 vehicles) in 2000 in countries that are members of IRTAD



Source: IRTAD

One important reason why Sweden has been successful in the area of traffic safety is that the effectiveness of knowledge-based safety measures was recognised at an early stage. Sweden has also invested significant resources in traffic safety research during the last fifty years. This study concludes that public funding and input into VINNOVA and its predecessors and the Programme Council for Vehicle Research (PFF) have contributed to the following:

- Annually Sweden saves 481 lives, which represents a societal benefit of SEK 8.4 billion and prevents many serious and minor injuries in traffic accidents
- The Swedish car industry has developed a number of safety products which favourably influences its global competitiveness
- Swedish research is of a high academic level
- Sweden has built up institutions that educate highly competent professionals within all areas of traffic safety.

Objective of the evaluation study

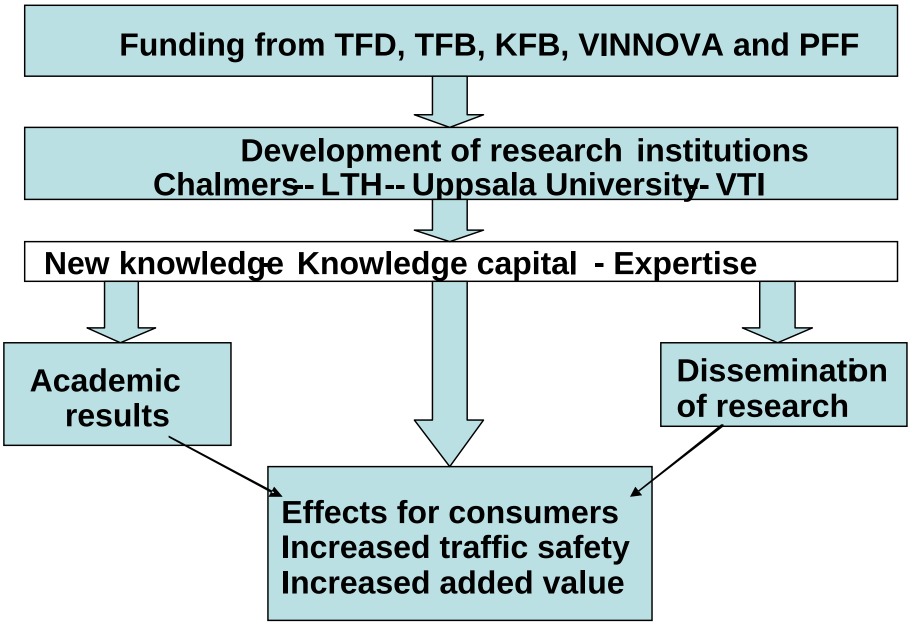
A previous evaluation of Swedish whiplash injuries research found great benefits for society, industry and research. On the basis of this, VINNOVA wanted a broader study of the effects of Swedish traffic safety research.

The Institute of Transport Economics (TØI) and Møreforsking Molde (MFM) have therefore carried out an evaluation study in order to answer the following questions:

- What effects and benefits has publicly- funded traffic safety research generated for research, industry and society?
- Which mechanisms have been particularly significant for the effects that have been achieved?

The analysis focuses on effect chains, from funding research to the behaviours of the research institutions and different forms of dissemination of knowledge to the end results such as a reduction in the numbers of killed/ injured in traffic and increased added value in Swedish safety-related industry (figure S.2). The design and results of the study have been discussed with Swedish research institutions and VINNOVA as part of the project.

Figure S.2: Effects of publicly funded Swedish traffic safety research – a model of effect chains



Accidents occur as a result of a failure in the interaction between the three main elements of the traffic system – the road user, the vehicle and the road/ surroundings – and between these and the regulatory system. Hence the starting point for our analysis is that traffic safety should be seen in a system perspective.

Comprehensive public focus

Traffic safety research is largely research directed towards one sector- the transport sector. Sector research can and must be based upon more basic research done by the universities and can itself contribute to this kind of research. Nonetheless, it requires separate funding, since scientific research councils do not normally support sector research.

The history of traffic safety research in Sweden goes back to the 1940s, and from 1949 to 2000 there were sector specific support bodies. The study covers the period 1971 – 2004. As complete data for research funding is not available for the years before 1974, this is used as the starting point. The analysis focuses on the contributions of the following public funding bodies:

- Swedish Transport Research Delegation (TFD)
- Swedish Transport Research Board (TFB)
- Swedish Transport and Communications Research Board (KFB)
- Swedish Governmental Agency for Innovation Systems (VINNOVA)
- Programme Council for Vehicle Research (PFF)

The first four are actually the same body, renamed as a result of numerous re-organisations, while PFF is a collaboration between the state and industry that started in 1994. Both PFF and VINNOVA normally require that projects be funded jointly with industry or with other public bodies. This kind of additional funding is not included in the analysis.

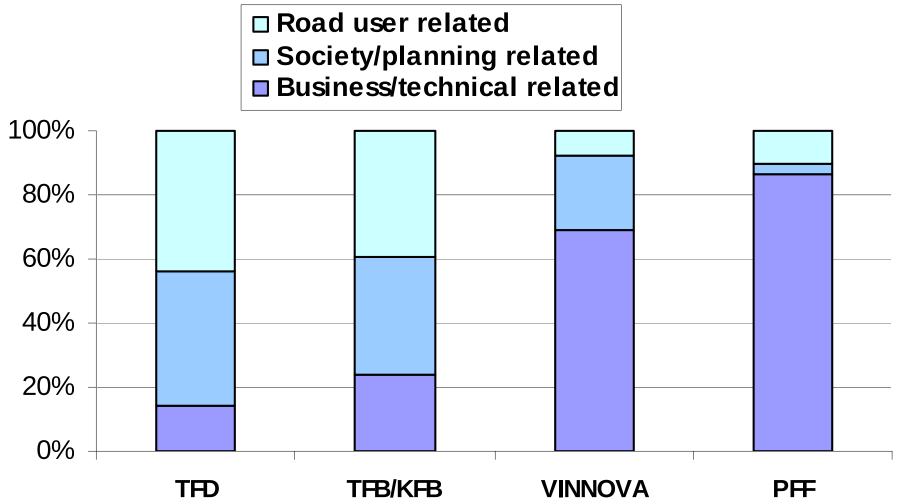
For many years, Swedish society has invested relatively large sums in traffic safety research. In total the five bodies listed above have granted SEK 0.44 billion between 1974 – 2004 (table S.2).

After KFB was merged with other research councils in 2000 and VINNOVA took over, annual funding has been somewhat curtailed and its direction has changed. The focus is now more on industry-related research (including technology and biomechanics) than it was before (figure S.3).

Table S.2: Traffic safety research funded by TFD, TFB, KFB, VINNOVA and PFF 1974-2004. Number of projects and million SEK (2000 values). SEK 12.7 mill ion for other objectives comes in addition to this

Source	Period	Grant in mill SEK	Number of projects	Mean annual grant mill SEK
TFD	1971-88	101.8	112	4.6-11.0
TFB/	1988-93	232.1	279	13.0
KFB	1993-00			
VINNOVA	2001 --	33.3	13	10.3
PFF	1994 --	60.6	30	8.4
Total		**427.8**	**434**	

Figure S.3: Research funding from TFD, TFB/KFB, VINOVA and PFF in the period 1974 -2004 according to subject content of project. Proportion of projects (N=431)



The funding bodies that have been studied are not the only contributors to Swedish traffic safety research. This research has also been granted significant funding from state and municipal authorities and from industry and insurance. In addition, public funding has been given in the form of basic research grants to the universities and research institutions such as the Swedish National Road and Transport Research Institute (VTI). However the contributions from other public sources have not been studied in this project.

The Swedish National Road Administration (VV), which is a major player in this field, has funded research and contributed to the development of research institutions through separate departmental programmes and funding for investigations, and also administers the Registration Plate Trust Fund. The Road Safety Inspectorate and the National Traffic Safety Administration, which existed between 1968-1993, have also played an important role. At the international level the EU’s framework programme has been particularly significant.

Most of the funding goes to the university and the institutes

The majority of the funding from the research councils has gone to universities and universities of technology or to research institutes. These account for 58 % and 26 % of the projects respectively, making a total of 84 %. VINNOVA and its predecessors, and PFF have invested heavily in creating research insti-tutions and a total of 60 % of the funding has gone to the following four institutions, which occupy a leading position within Swedish traffic safety research:

- Department of Applied Traffic Safety (TTS), Chalmers Technical University (Chalmers) –
  SEK 56.7 million spread across 34 projects
- Department of Technology and Society, Lund Institute of Technology (LTH) –
  SEK 47.4 million spread across 62 projects.
- Department of Psychology, Uppsala University –
  SEK 47.8 million spread across 54 projects
- The Swedish National Road and Transport Research Institute (VTI)–
  SEK 102.7 million spread over 105 projects.

While TFD, TFB and KFB spread their funding across all the above institutions, PFF and VINNOVA have so far only supported Chalmers and VTI.

The rest of the funding is divided relatively evenly across 105 institutions. Beyond the four main institutions, six other institutions have taken on more than five projects. The input into the smaller institutions has often been done in co-operation with the larger institutions.

The evaluation is limited to the four institutes listed above. Case studies have been chosen to cover at least one of each of the environment’s areas of work, namely:

1 Speed reduction measures in towns/ cities, including roundabouts (LTH)
2 Developing and standardising rearward facing child seats in cars (VTI and Chalmers)
3 Developing better protection against neck injuries and side impact protection (Chalmers)
4 More effective police enforcement against speeding and drink driving (Uppsala University and VTI)
5 Development and use of VTI’s driving simulator (VTI)

This means that the report does not go in depth into other important Swedish research areas, such as trials with ISA (Intelligent Speed Adaptation), Driver training, Stability of heavy vehicles, Children in Traffic, The power model of the relationship between speed and road safety or Conflict studies – theory and methodology - for studies of interaction in traffic.

Sweden is a safe country – research has contributed to this

From 1970 to 2005 the number of fatalities in Swedish traffic has gone down by about 67 % (from 1307 to 440) and the number of seriously injured by about 45 %. Given that road traffic during the same period has increased by over 100 % (from 37 to 77 billion vehicle kilometres), the risk of being killed or injured in traffic in Sweden has been reduced by over 80 % and 50 % respectively. In other words, every road user now travels more safely than before.

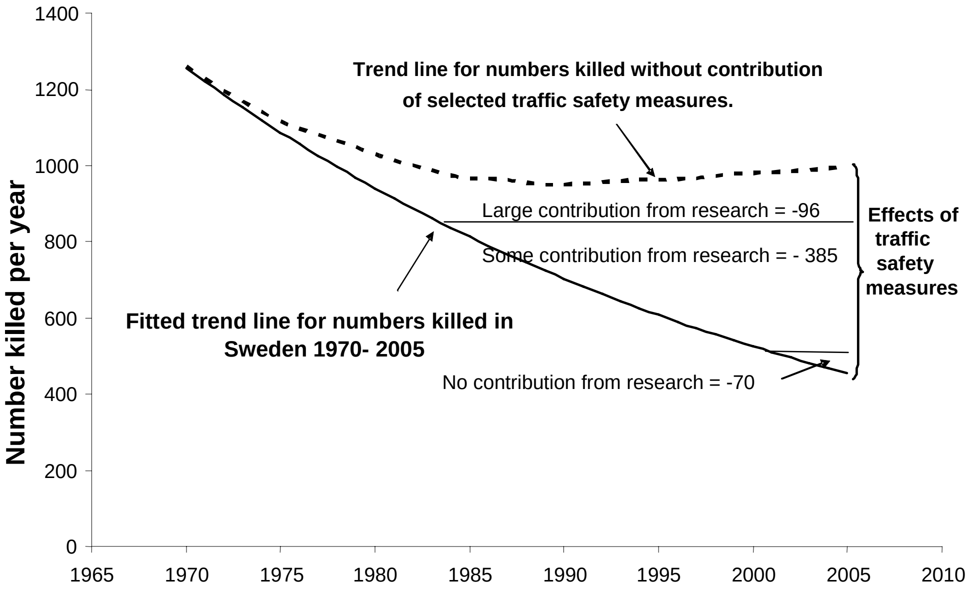
We have tried to estimate the contributions of different factors to the improved road safety in Sweden after 1970, and the extent to which the different measures have been based on research. The study is limited to factors that have been widely tested in practice and where previous evaluation studies provide a basis for estimating their effects. Other factors may be equally important, but their effects cannot be estimated on the basis of the available data. It is important to be aware of this when interpreting the results.

The importance of research for the development and use of safety measures has been assessed in terms of the amount of research done in the different areas, the country of origin of the research and its impact in Sweden.

In total, the factors included in the analysis may account for a reduction in the annual death toll in Swedish traffic of 551 people. Figure S.4 shows the development in the numbers killed and the unobserved counterfactual development that might have taken place *without* the factors whose effects have been estimated. Even without the measures and the development trends included in the study, a decrease in the number killed in Sweden would have been expected.

Research and research-based safety measures have contributed significantly to the large reduction in the numbers killed in traffic accidents in Sweden. Figure S.4 shows that measures that to a large extent are based on traffic safety research, may have reduced the numbers killed by 96 persons per year. Measures where research has provided a significant contribution may have reduced the numbers killed by 385. Factors not influenced by research are estimated to have contributed to an annual reduction in road deaths of 70 people.

Figure S.4: Long-term development of numbers killed in Sweden. Trend line fitted to actual data and curve showing possible development without contributions from selected traffic safety measures and the significance of traffic safety research.

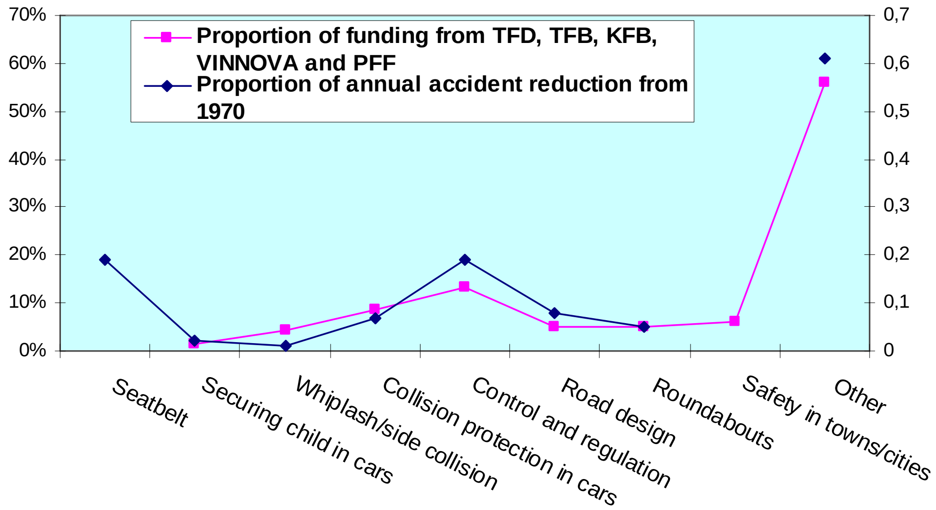


Comment: The total number killed, resulting from different measures, does not take into account any interaction between the measures.

We have also classified research projects according to the type of road safety measure they are most closely related to in the combined portfolio for VINNOVA and its predecessors and FFP, and assessed whether the size of research funding is statistically related to the estimated size of the effects of the road safety measures (figure S.5). The effect of seat belts is included even though much of the research input dates from before 1971.

Figure S.5 further shows the amount of research for safety measures in towns and cities other than for accidents at crossroads, even though we do not know the safety effects of the different measures. However, we do know that safety in Swedish towns and cities has increased significantly.

Figure S.5: Calculated effect of different traffic safety measures and research input (number of projects) within groups of measures supported by VINNOVA and its predecessors and PFF in the period 1974-2004



In other words, it can be concluded overall that the funding provided by VINNOVA and its predecessors and PFF has contributed to improving road safety and that investments have been made in important project areas.

Investment has provided great socio-economic benefits

In a macro perspective, Swedish traffic safety research has been found to be useful. The estimated effect on road accident fatalities of all the factors that have been studied, all of which were based on a (large or given) research input, amounts to 481 lives saved per year. This represents a socio economic benefit of SEK 8.4 billion, based on SIKA's evaluation of a human life as SEK 17.5 million (2001-prices). The benefit far exceeds the support from VINNOVA with its predecessors and PFF. If we also take those injured in traffic accidents into account, the benefit is several times higher, see table S.1.

In the case studies, we find that:

- Speed reduction measures in Swedish towns and cities have given a socio- economic benefit (present value) of SEK 17.1 billion for a total cost of SEK 6.9 billion. It is estimated that the measure has contributed to 40 fewer being killed, 170 fewer being seriously injured and 180 fewer minor injuries per year
- The benefit to society of child restraints in cars is SEK 1 350 million (present value). The cost is estimated at SEK 210 million. The measure has contributed to 16 fewer fatalities, 38 fewer seriously injured and 504 fewer minor injuries per year.

- The benefit of better neck injury protection (whiplash) in new vehicles is estimated at SEK 1.9 billion (present value), while the development costs are calculated to be about SEK 100 million and the costs for car buyers are around SEK 100 million. The measure has contributed to 63 fewer seriously injured and 250 fewer minor injuries.
- The benefit of side impact air bags is estimated to be SEK 4.6 billion (present value). The costs can be estimated at around SEK 450 million. The measure is estimated to have contributed to 10 fewer fatalities and 75 fewer seriously injured per year. No data is available for minor injuries.
- More effective police enforcement has contributed to 150 fewer fatalities per year, 250 fewer seriously injured and 220 fewer minor injuries. The annual cost of police enforcement in Sweden is around SEK 500 million. The benefit in the form of fewer people being injured or killed is estimated to be around SEK 3.4 billion per year.

The measures included in the case studies have produced a major net benefit, amounting to around SEK 20 billion in total. The figure is not exact as it is difficult to calculate a total ”savings” benefit over a number of years for different measures. This particularly applies to police enforcement where the benefit normally occurs during the period when it is taking place.

The estimates refer to the benefit for Swedish society of the research based measures, but products/ measures that the research has initiated, will also have benefits outside Sweden. The value of these is not included in the figures.

Effects on society’s way of thinking

Through their input, VINNOVA with its predecessors and PFF have ensured long-term co-operation between researchers and users. This has led to effective use of research results, including changes in perspective and also enabling researchers and users to develop a joint understanding of questions and problems.

The rearward facing child seat is a good example of how an innovation in research can revolutionise our way of thinking. The car industry, the traffic authorities and the insurance industry's joint concept of ”the Swedish child seat culture” is an expression of this. By understanding that a child's body cannot withstand collision forces in the same way as an adult, realisation has dawned that children are not small adults and they have different physical and psychological requirements and abilities. This has also been significant for planning measures to protect children in traffic.

Similarly we find that a successful emphasis on traffic safety in towns can be copied to a research- based way of thinking. This has been demonstrated in cities such as Växjö and Göteborg, where VINNOVA's predecessors, TFD, TFB and KFB, have supported different projects. The Swedish Vision Zero is an example of how research-based knowledge has changed the perspective on where the focus should lie in traffic safety policy and which measures are effective.

These effects are not only national. The Swedish traffic safety discussion has had great influence in the EU and we find the Swedish argument for shared responsibility, ”forgiving” roads and road surroundings in the EU's policy documents. It can also be mentioned that the ISA concept (ISA = Intelligent Speed Adaption), where research began at LTH in Sweden, is beginning to gain a foothold within the EU.

Traffic safety is an important part of the Swedish trademark. It is well known within the EU system that professionals in Sweden invariably have a high level of expertise and have achieved good results within this field. Sweden has been in a position to impose a successful traffic safety policy partly due to the fact that the policy is based on solid research. It has been possible to adopt relatively broad decisions regarding traffic safety because it has been possible to justify the decisions by referring to large, documented effects.

There is also the fact that the Swedish traffic safety system is research-intensive that has made it possible to export this. Research-based knowledge, where the effects of measures have been systematically studied using scientific methods, allows others to check and utilise the results.

Sweden is regarded from outside as one of the countries where you can rest assured that traffic safety measures will not just be set by law but will also be implemented and evaluated. The basis for this successful policy appears to be knowledge of the causes of accidents or injuries, which in turn makes it possible to carry out effective prevention. The rationality in the system is therefore important in Sweden's international influence in this field, and this rationality is contingent upon highly competent research institutions.

Focusing on safety is also valuable for Swedish vehicle related industries

Right from the start, Swedish traffic safety research has had a close relationship with different sectors of society. The National Road Safety Council, which operated between 1949 and 1971, had members from the authorities, organisations and industry on its board. The link to the vehicle industry for example was an important precondition for the rearwards facing child car seat going into production relatively quickly. The link to authorities and organisations contributed to laws and other measures which accelerated their use.

The case studies involving safety systems developed by industry all show that the link between basic research (in medicine, psychology, biomechanics) and industry has been decisive for the results which have been achieved. Knowledge of the biomechanics leading to whiplash injuries has made it possible for Volvo Car Corporation, Saab and Autoliv to develop competitive, innovative products.

The co-operation with VTI and using their advanced simulator has also been fundamental for the development and has contributed to PhD projects and the development of the necessary expertise to get ahead in international competition. In industry it is not regarded as possible to develop traffic safety products that are not based on research.

Autoliv, Volvo Car Corporation and Chalmers are now working together on the further development of the BioRID crash test dummy and the American dummy THOR, to a ”multidirectional” frontal collision dummy. PFF is involved in financing the project that is also developing dummies in women and child sizes. On the basis of this research, Autoliv, together with Chalmers and Folksam (insurance company), is working on improving frontal airbags and the overall protection afforded by seat belts and airbags with respect to neck injuries.

New vehicle based systems for preventing accidents have gained increased attention recently from Autoliv, Chalmers and vehicle manufacturers. These are electronic systems which help the driver avoid accidents or to reduce the effect of accidents by reducing engine power or by active intervention. Research into these types of systems requires knowledge of both biomechanics and human behaviour. A new generation of products within this field will come onto the market and is expected to have major commercial potential.

The report also tries to estimate the added value in Swedish industry as a result of the products based on Chalmers' research into whiplash. Autoliv, which is one of the world's leading manufacturers of safety equipment for cars, estimated in 2002 that the global market for side-on impact protection was around SEK 10 billion. The industry's producer surplus in Sweden was estimated to be SEK 920 million per year. This estimate is based on the costs of producing the equipment, as it is assumed that the benefit from the products on the market is *at least as great* as the costs of producing them, otherwise they would not have been marketed. The real benefit is obviously greater but cannot be calculated precisely.

The total socio economic benefit for Swedish society of better safety as a result of focusing on research is high, and industry also shares the benefits in that safer vehicles (produced in Sweden) sell better than less safe vehicles (wherever they are made)

Industry has also benefited from research support for projects such as building infrastructure (simulators) and developing products (crash dummies). Funding for PhD students and the development of expertise at the universities have enabled industry to buy services from these institutions and given them access to competent staff. The case studies clearly illustrate that state support for these products has also been useful for industry.

Qualified research institutions within traffic safety research have been of great significance in supplying the vehicle industry with expertise. This may have been decisive for the production of vehicles and equipment still being based in Sweden; even after Ford and GM took over Volvo Car Corporation and Saab respectively.

Traffic safety and safer vehicles are valuable trademarks for Sweden. Increased competition will mean that Swedish research co-operation will face major challenges in the future. The on-going development of the infrastructure for research at Lindholmen in Göteborg concerning the vehicle industry cluster is an important measure for further developing comparative advantages in Swedish safety- related vehicle- and supply industries. These include Test Site Sweden and the new safety research centre SAFER. Both Chalmers and VTI are a part of this, together with VINNOVA and a number of industrial partners.

Strong, diverse research institutions have had an effect

Support from VINNOVA and its predecessors and PFF have laid the foundations for a number of strong Swedish research institutions in the area of traffic safety. The following have been achieved:

1. Several universities have elected to focus on traffic safety in their research and teaching
2. Research which is of a high international standard and researchers who actively participate in international research co-operation
3. The development of research institutions with complementary disciplinary specialties
4. Ensuring professionals within Sweden who can fulfil expert roles and disseminate international research.

Teaching in the field of traffic safety is very important in order to ensure highly competent co-workers in Swedish administration and industry. Further education for administration at the municipal level is an important activity at both LTH and VTI, which have both spread Swedish expertise through courses in a number of developing countries. Uppsala University has trained psychologists for the other institutions and Chalmers has contributed with different types of expertise for industry.

Research funded by VINNOVA and its predecessors and PFF is of a high international standard, has good international coverage and the players participate in international organisations. Sweden's share of articles in *Accident Analysis and Prevention, Journal of Safety Research* and *Safety Science* (the highest ranked scientific journals within the field according to the *Institute of Scientific Information*) in the period 2000-2005, for example, was 6.7 %, while England had 8.6 % of the articles.

Representatives for DGTREN[1] and ETSC[2] estimate that Swedish research institutions are amongst the best in Europe, which is also supported by the fact that Sweden takes part in about half of the projects in the area of traffic safety in the EU 6th framework programme. VTI and Chalmers have been particularly active in the EU system and the 6th framework programme and LTH is also actively participating in international project co-operation.

The diversity of topics covered applies either to what we see in the thematic profile (figure S.6), or the areas of measures where funding has been obtained. Chalmers focuses on technical, biomechanical and business-related research, while Uppsala University has concentrated on road user-related research. LTH has a high level of expertise in planning in towns and cities, developing road systems and in understanding conflicts and interaction between roads and road users.

As a sector institute in the area of transport, VTI naturally has a broad spread of activities and around 40 % of VTI's work is linked to the area of traffic safety. VTI has access to technology for testing safety equipment such as collision tracks and driving simulators. They also work with traffic-related research: use of safety equipment, driver training and children in traffic. Analyses of accidents and factors influencing them are another core area at VTI.

Traffic is an interaction between road users, vehicles and roads. Knowledge of all these three elements is therefore required in order to increase safety. The fact that the research institutions have developed different profiles has clearly been a strength for Swedish traffic safety, since this breadth has given society a professional research basis for many of the areas that make

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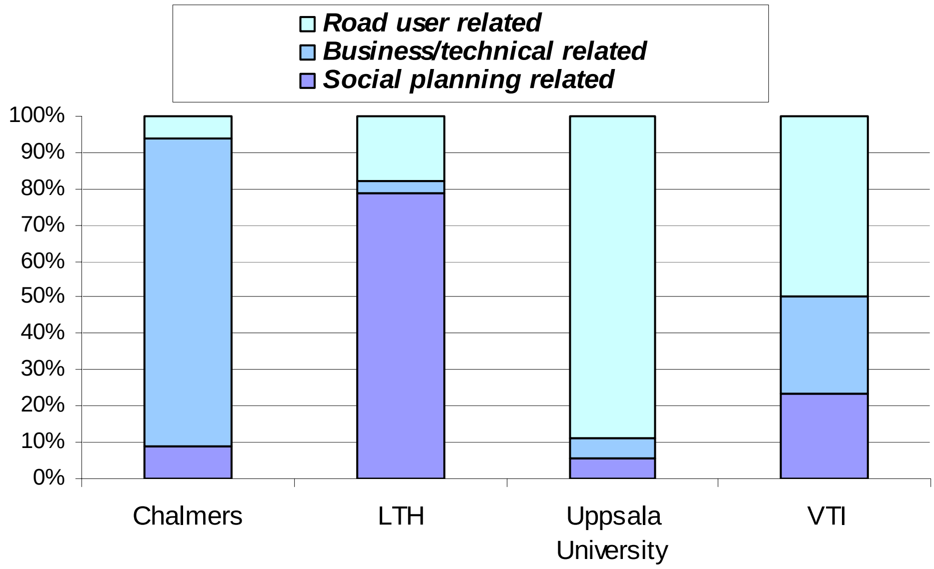
[1] DG TREN (*Directorate General for Energy and Transport*) is responsible for development within transport and energy policies and finances, and organises much of the EU- funded research within traffic safety.

[2] ETSC (*European Transport Safety Council*) is an independent organisation which works with European decision makers to promote traffic safety. The organisation is funded by the member organisations, the EU commission and through sponsorship funding.

up the traffic system. With good access to resources, the research institutions have not felt that they are competing with each other, but have been able to draw upon each other as required.

Figure S.6: Research funding from VINNOVA and its predecessors and PFF for four Swedish traffic safety research institutions from 1974-2004 according to the subject content of the project. Proportion of projects (N=253)



An illustration of this is research into police enforcement at Uppsala University and VTI. The research at Uppsala compared the effectiveness of various techniques of enforcement, while the research at VTI documented the need for enforcement by demonstrating the significance of speed for safety and by showing that speeding is very common. This convinced the authorities to focus more on enforcement as an effective measure.

Swedish traffic safety research – an example of a good research circle

Expertise within traffic safety in Sweden is very good and there is no doubt that the funding from VINNOVA and its predecessors and PFF has created what we call a good research circle. Swedish research has contributed to adding value in the vehicle related industry and to policy development in the area of traffic safety both nationally and internationally

The quality of the research is a necessary condition for creating a good research circle (figure 7). This is often underrated in discussions about what contributes to innovation and creative processes. Where unity in the mechanism contributes to developing high quality research, this will enable spin-offs in all directions. High quality generates both more users and more demanding users, which will motivate the research institutions to raise the quality even further.

With high quality and users who have an understanding of the importance of basing their choices, strategies and actions on research knowledge, the probability of good results for society and for industry also increases. Good mechanisms for making the results and the effects visible creates better opportunities for research and innovation.

Figure S.7: An illustration of a good research circle with effects for society and for industry.

The following elements characterise the Swedish focus on safety research:

- Understanding the significance of knowledge and tradition for the systematic evaluation of measures in the area of traffic safety amongst Swedish politicians and authorities, which for almost sixty years have set aside public resources for safety research.
- Developing highly competent research institutions that together cover the most important challenges within the road user - vehicle - road interaction that causes deaths and serious injuries in traffic. Swedish administrative bodies have thus obtained tools for managing traffic safety from a system perspective.
- The funding systems have contributed to the development of networks and arenas for learning and interaction. Highly competent users in administration and industry ask for research to be carried out, and have paved the way for important knowledge being converted into practice in administration and in industry.

The network of researchers and other professionals have contributed to the diffusion and dissemination of knowledge to the whole of society. This has contributed to changes in the way of thinking and to visions and strategies for traffic safety work based on scientific knowledge. Organisations and municipalities have also contributed to these effects.

What makes a good research circle?

The good research circle illustrates the significance of quality. The research institutions' self-evaluations, dialogues with them and with users, the five case studies and corresponding evaluation studies in other countries provide some important conditions for achieving this type of circle:

- Focus on increasing expertise through support for the education system and basic research combined with incentives in order to ensure that the discipline-related research at universities and polytechnics elects to work on traffic safety in their research, their PhD programmes and in their teaching. The support systems have ensured that there is prestige in working in safety research.
- Competent and non-bureaucratic support for researchers and research institutions is vital to get the best possible return for the input. All the institutions in the study emphasise simple, competent handling of applications as an important characteristic of VINNOVA and its predecessors and PFF.
- The research institutions stressed the fact that during the period from 1971-2000 they had relatively stable and predictable funding for example through thematic programmes, rather than fundraising for individual projects.
- The research institutions have received support during critical phases when other sources have not provided support or shown interest.
- The breadth and size of the focus from 1971 has opened the way for cross- disciplinary innovation and for interaction rather than competition. The breadth indicates a willingness to take risks on the part of the funders that has paid off and has created greater chances for dealing with unexpected knowledge demands.
- Making the effects visible in a form that the grant -making authorities can understand, for example through socio-economic measurements of results, has contributed to demonstrating the relevance of the research. This has been an important way to increase the funding levels.
- Good contact with the whole user spectrum has also contributed to overturning practical and political barriers to implementation. Contact with the users has also contributed to the research results being ”packaged” in a suitable way.
- There are also good circle effects in the support that is given to international activities and participation. This has led to a raising of quality that has in turn resulted in spin-offs both nationally and internationally.

The good research circle illustrates the need for overall responsibility for unity in the whole mechanism. Our main impression is that VINNOVA with its predecessors and PFF in many ways have created the way to run a good research circle. After KFB was dismantled in 2000, conditions changed, so that there was no longer one single authority with a total, all-encompassing responsibility for Swedish traffic safety research.

The research institutions that we have interviewed, express some unease for financing doctoral programmes and for the long -term, fundamental development of knowledge and theory development within traffic safety in the future. It is the support for such activities that has given the university institutions incentives to put time into traffic safety research. No matter where they come from, the interviewees also state the need for resources for behavioural science and planning-related research.

A total, all-encompassing responsibility for Swedish traffic safety research over fifty years has ensured that there have been no gaps in the funding of long term research or for important parts of the unity which is needed in order to understand and manage traffic safety in a system perspective. Sharing responsibility between VINNOVA and Vägverket (Swedish Road Administration) imposes new demands for co-operation between the players if the breadth and long-term perspective of the research are to be dealt with in the best possible way.

Additionality in all directions

The evaluation has relied upon evaluation research's understanding of additionality as a central concept for describing effect chains:

- *Input additionality* describes the degree to which different tools contribute to increased research input and institutional development and measures the accuracy of what happens by releasing more research funding. We find clear examples where such support has released new funds from industry.
- *Behavioural additionality* shows how the tools, here the public research funding, affects the behaviour in a complex system. Effects that we have seen are better links between research institutions and industry/ administration, and changes in the external players' behaviours as a result of new knowledge, innovations and product development.
- *Output additionality* characterises the end results of the effect chains. In the analysis, the benefits to society of fewer deaths/ injuries have been estimated, together with the increased added value for Swedish industry, specifically the vehicle manufacturing industry. Additional effects include improved competitive ability and increased exports as a result of a head start in safety inbuilt in Swedish vehicles and Swedish safety equipment.

In order to make the different types of effects visible, we have used several perspectives and a combination of methods. The study utilised a socio-economic perspective in order to quantify given parts of the benefit gained in crowns for Swedish society and for industry and to weigh this up against the costs. Many factors will fall outside this type of analysis but it provides an indication of the size of the value of the research input.

Use of knowledge occurs both directly and indirectly and over very different time spans. We have therefore concentrated on obtaining data for effects where values cannot be so easily quantified. In order to obtain an understanding of a more diffuse transfer of knowledge, of what contributes to effects, of how support arrangements and effect potential are evaluated, we have used qualitative methods: document analysis, interviews, group discussions and self evaluations.

One challenge is that research is often not the only knowledge base and nor is it a sufficient condition for achieving effects. Research that is not used can nonetheless be useful. It can provide background knowledge and help to inform choices, and it can be fundamentally important in meeting future knowledge requirements.

On the basis of this study we can maintain that Swedish traffic safety research has had significant effects for traffic safety and the vehicle manufacturing industry in Sweden, and that these effects would probably not have occurred to the same extent without the long-term, broad focus on such research that has been provided by TFD, TFB, KFB, VINNOVA and PFF. The public research funding has provided additionality in all areas, in the form of increased input from other sources of funding focus on safety in important research institutions and a number of significant effects for society.

Introduction

Background and purpose

By request of the Swedish government, VINNOVA produces impact analyses of its focus areas annually, and in 2005 and 2006 the focus has been on road safety research. Road accidents are a very serious social problem, estimated by WHO to become the world's third largest health problem in the years ahead (Murray and Lopez 1996). An earlier impact analysis of Swedish research into whiplash injuries (Eriksen et al 2004) – documents that public research support has been of major significance to industry and in limiting the consequences of road accidents. It is therefore natural to carry out research to find out whether similar effects are present in other areas of road safety research. It may also be appropriate to study safety research in view of the discussion pertaining to the restructuring of transport research from 2001 (Wijkmark 2004, VINNOVA Policy 2004).

The impact analysis of Swedish road safety research has two maingoals: one factual and one strategic;

- *lFactual:* what impacts and what benefits does publicly funded safety research have for research, industry and society?
- *Strategic:* what mechanisms have contributed to the impact and how can we pave the way for good results in the future??

Both goals are related to important transport-[3,] industry and research[4]-policy targets. However the impact analysis is not intended to evaluate the extent to which the main objectives, for example the sub-objective of the area of safety have actually been achieved or not. In order to carry out such an evaluation, other elements must be taken into account alongside research funding (see for example Assum and Hedegård Sørensen 2005).

Work on the impact analysis has been carried out in several stages. In the spring of 2005, VINNOVA held a series of seminars and dialogues with key players within Swedish road safety work and with Swedish specialist in the field from various institutes. In addition, an historic overview of Swedish road safety research (Englund 2005) was compiled and the available data on

[3] Target for accident reduction, see the Government's proposition 2005/06:160 *Moderna* t*ransporter*
[4] Taget for connecting research and industry in the Government's (2005a) strategy: "*Fordonsindustrin – en del av Innovative Sweden*".

projects funded by VINNOVA and its predecessors between 1974 and 2004 was entered into a database at VINNOVA.

In the autumn of 2005, the Institute of Transport Economics (TØI) and Møreforskning Molde (MFM) were commissioned to develop a system for a broader impact analysis. Analyses of VINNOVA's project database, document studies, written self-evaluations and dialogues with representatives of selected Swedish researchers provided an overview of the field. Models for impact analysis, operationalising impacts, criteria for quantifying impacts, challenges of impact analyses and actual case studies were discussed with Swedish research institutions and staff from VINNOVA in April 2006.

The last part of the impact analysis has covered more fundamental analyses of selected case studies, different users views, international aspects and factors that have influenced road safety development, and was carried out in the autumn of 2006. During this phase as well, the preliminary results were discussed with the research institutes, users of the research and representatives of those commissioning the work.

Focus and delimitation

Road safety research in Sweden has a long history reaching back to the 1940s (Englund 2000a, 2005). This impact analysis covers the period from 1971 – 2004[5], and focuses on the contributions from to the following public funding bodies;

- Swedish Transport Research Delegation (TFD) from 1971 – 1987/88
- Swedish Transport Research Board (TFB) from 1988 – 1992/93
- Swedish Transport and Communications Research Board (KFB) from 1993 – 2000
- VINNOVA – Swedish Governmental Agency for Innovation Systems - from 2001 -
- Programme Council for Vehicle Research (PFF[6]) from 1994 –

VINNOVA and its predecessors and PFF are not the only institutions to fund road safety research. Other public sources of funding are the Ministry

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[5] We use somewhat different time periods in the analyses;
The impact analyses, comissioned by VINNOVA, applies to the period from 1971 (when TFD was set up) to 2004
Road safety development is analysed from 1970 -2005, which was simplest considering the available database
The analyses of project allocation and project profiles in different enviroments institutions etc based on VINNOVA's database are done from 1974, as there is no data for individual projects from 1971 to 1973.

[6] PFF has four programmes of which one is the Fordonsforskningsprogrammet (ffp). WE only look at projects under ffp in this analysis.

of Trade and Industry that provides basic funding for research institutions within the transport sector, such as Vägverket, Banverket, Vägtrafikinspektionen as well as municipal bodies. We have not collected information on the contributions from other bodies, and this does not necessarily give the best insight into how to allocate the “glory” for the impacts according to the proportion of funding from the various sources. We have only looked at the relationship between the sources of funding where it concerns the budget of selected institutions.

There are four research institutions that have a particularly prominent place in Swedish road safety research from the 1970s onwards, namely (the names used in the report are in parentheses):

1 Department of Applied Traffic Safety (TTS), Chalmers University of Technology (Chalmers).
2 Department of Technology and Society Lund University (LTH)
3 The Department of Psychology, University of Uppsala (University of Uppsala)
4 Swedish National Road and Transport Research Institute (VTI)

More in depth studies of impacts of research are limited to these four institutions. We have not collected separate data from other smaller specialist institutions, or studied in detail the interaction between these and the four large institutions. Nor have we looked into all the research topics that VINNOVA and its predecessors or PFF have supported in this period, but have chosen the following case studies in order to cover at least one of each of the four work areas of the leading institutions;

1 Speed reducing measures in towns/ cities, including roundabouts (LTH[7])
2 Development and standardisation of rearwards facing child seats in cars (VTI and Chalmers)
3 Development of improved protection against whiplash injuries and side impacts (Chalmers)
4 Effective policeenforcement– targeted at speeding and drink driving (Uppsala University and VTI)
5 Development and use of VTI’s driving simulator (VTI)

This means that the analysis does not go into depth into a number of other important Swedish research areas such as tests with ISA (Intelligent Speed Adaptation), Heavy vehicle stability, Driver training, the Power Model of the relationship between speed and accident risk or Conflict theory and methodology for studies of the interaction in traffic.

[7] The ”stadsbyggnadsenheten” at Chalmers has also worked on this previously .

The structure and content of the report

The analysis seeks to make clear the impacts – not only on research, society and industry – but also at different levels, like society as a whole, in given research institutes and related to specific projects. Data collection and analysis have therefore been undertaken at a macro and micro level. At the macro level, the project has established a framework for understanding and has investigated impacts on the whole of society, while at the micro level we have tried to deepen understanding through case studies of research institutes and research fields. By linking these various levels, we can obtain an overall picture of the impacts and the mechanisms that have been significant.

We have divided the report into three parts:

- *PART I – the framework for the analyses*
  In Chapter 1, our analysis model is first presented and the multi dimensional methodological system that has been necessary to be able to carry out the impact analysis. In chapter 2, we describe how road safety has developed in the period between 1970 – 2005. The positive development with regard to safety on our roads and understanding the contribution to the field of road safety requires a system perspective is an important background for the analysis. The development of road safety research in the same period is described in chapters 3 and 4. While chapter 3 deals with the budget constraints, chapter 4 deals with the basis for all forms of impacts of research investments, namely the people and institutions that carry out the research.
- *PART II - impacts of public research funding – VINNOVA and its predecessors and PFF respectively*
  This part attempts to highlight different impact and questions related to the factual part of the analysis. Chapter 5 deals with the impact of the input of the four major research environments, with specific focus on measurable academic results, from publishing to education. In chapter 6 we attempt – on the basis of case studies and interviews with the users – to give a picture of the different impacts on the manufacturing industry. In chapter 7, we present an analysis of the significance of road safety research for risk development at the macro level. Here we also explore the relationship between funding of research and the impact a given safety measure has in practice. Finally in chapter 8 we look at the impact on policy development and ways of thinking both nationally and internationally.

- *PART III – Reflections on mechanisms for impacts* In this part the strategic purpose is central. Here we attempt to clarify the prerequisites for the impacts that have been shown in part II. Chapter 9 summarises the importance of the contribution of VINNOVA and its predecessors and PFF. The good results create the starting point for describing what we call a good research circle. This is a process that characterises the history of impacts of Swedish road safety research. In chapter 10, based on experiences from the period 1970-2004, we also try to find out what has contributed to a good research circle.

References, overviews of informants (Appendix 1), tables (Appendix 2) and five complete reports from the project's case studies (Appendix 3-7) are attached to this report.

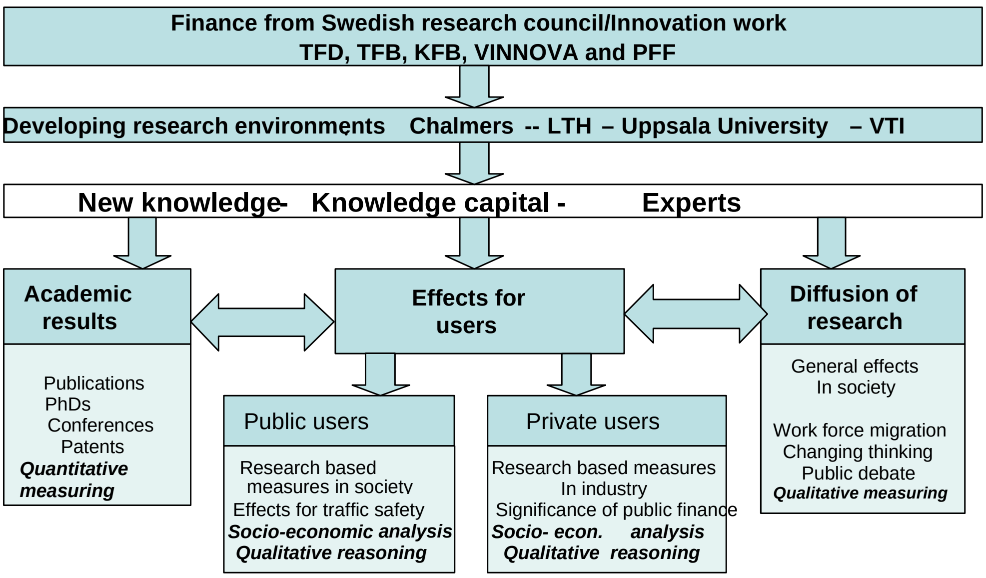
PART I - The framework for the analyses

1 Basic assumptions and method of the impact analysis

1.1 A model for analysing impact chains

The impact analysis will study the significance of public financial support for research to promote road safety and industrial development. A simplified model of factors which need to be focused upon in this type of task is shown in figure 1.1. The aim is to demonstrate the impact – not only in the three spheres of research, society and industry – but also to indicate the impact chains from research funding via the behaviour of the research institutions (for example, institutional development) via different forms of diffusion of knowledge to end results such as a reduction in the numbers of fatalities/ injured and in increased added value for Swedish accident-related industries.

Figure 1.1: Impacts of publicly financed Swedish road safety research – a model of impact chains



As the model shows, we think of impact at several levels. The development of research institutions and expert networks that can develop and administer the knowledge capital is a first step, and a prerequisite for all other impacts.

In this way it is possible to trigger funding from other sources. Institutions with highly developed competence provide the country with experts who can give advice and express opinions to society, and are also necessary for surveying and utilising international research results. The public funding contributors can have important network roles and can contribute to creating arenas for contacts and the exchange of knowledge. Networks are also created through the education and further education of practitioners. In a cluster and network perspective, road safety research can aim to bring together industry/research/society and/ or different experts in different fields in useful co-operative projects, create first class teaching at all levels, contribute to the recruitment of expert personnel for the manufacturing industry and the public administration and create meeting points for all the players concerned.

Impacts can only be demonstrated when it is possible to identify one form or another of a cause/ impact chain. Relatively clear causal links may exist, but to demonstrate such causality will often be almost impossible. In the analysis we will look at both the ”simplest” links where we can find users who use research results directly to produce their own results with demonstrable and possibly quantifiable impacts, and more indirect benefits of research for society. The latter type of impact can be best measured qualitatively, for example by demonstrating that knowledge is spread though better teaching, workforce migration, special and general information to politicians and other vocal people, and the participation by researchers in the public debate. Changes in attitudes to safety at different levels of society can be another expression of impact.

In the analysis, we try to bring out the benefit/ value of the different impact evaluated in relation to costs/ inputs. Benefits are evaluated economically, from a business economics perspective and more qualitatively. The evaluation is carried out according to the tenet of methodological evaluation research' that additionality is a central concept for demonstrating impact chains:

1 *Input additionality* describes the extent to which different measures for stimulating research contribute to increased research and institutional development and measures the success of a measure to trigger more funds for research. In our analyses, the financial support of TFD, TFB, KFB, VINNOVA and PFF is the input and we ask what their support and their way of organising this support have meant for safety research.

2 The concept of *behavioural additionalit*y attempts to investigate how measures affect behaviour in a complex system. For example, does the chosen strategy give university staff incentives to focus on road safety research? Does an altered strategy create stronger links between research institutions and industry/ administration? The behavioural aspect also covers how knowledge can alter the behaviour of external players and lead to innovations and product and process development.

3 *Output additionality* denotes the significance of finance for the end impact of the impact chain. In this analysis we use measurements of the benefit to society of fewer fatalities/ injuries as well as increased added valued in Swedish industries, for example an increased ability to compete and export as a result of a head start in safety built into Swedish cars and Swedish safety equipment, in order to obtain the end impact.

When a project is successful, impact analyses, with the help of different measurement units can identify what we call full input additionality. It is also important to identify cases when funding contributes to creating high additionality in the long term, for example by developing more research-intensive work. Behavioural additionality can be measured as increased publishing, educating PhDs, developing research networks, influencing road user behaviour and measures taken by the authorities, as well as an increase in the number of patents and innovations through product and process development. In a connected cause/ impact chain we will be able to identity a the final link as the output additionality in the form of a reduction in accidents and the number of fatalities / injuries and /or increased added value in the car industry as a result of the R&D input with full input additionality and high behavioural additionality.

1.2 Research into the application and returns of research

The application of and returns to research are a complex theme, which cannot easily be identified by a simple set of indicators and cannot be comprehended on the basis of a simple theory. While it is difficult to measure impact of Swedish road safety research over a period of 35 years, the application and impacts of research can only be evaluated over long periods of time (Louis 1999). In order to deal with this challenge, we must utilise elements from different theories and methodological approaches.

The basis of the analysis is the body of knowledge which previous research into the application and returns of research has provided. Studies of benefits of research are an established subject area, where the empirical research literature goes right back to the 1950s. A number of theoretical and empirical studies document high returns on investments in research and that the economic return on research is normally higher than the private economic returns (Griliches 1957 and 1995). Mansfield (1991a and 1991b) summarises ten different studies on the returns of research and finds that the private return rate lies in the interval 20-50 %. When the economic values are added, the return is more than doubled.

There are many methodological problems linked to measuring the added value of publicly funded research programmes or support arrangements. In evaluating research, in many cases the focus has been on the average return, thus ignoring the fact that the marginal projects will have a much lower return and that there may be a few projects with a particularly high benefit compared to costs. This problem has been well illustrated in Norwegian studies of returns of selective programme support. A sample of more than 1000 projects from user-steered programmes in the Norwegian Research Council has been followed as a panel study in the period 1996-2004 (Hervik et al 2005 and 2006). Some of the main findings are:

- In the long term, a handful of projects have a private financial return that is so large that it covers the costs of all the projects studied.
- The development of expertise, technology and networks appear to be more important for companies than the project's financial return.
- To a large extent, the projects create new knowledge. Result indicators for scientific publications, PhD studies and co-operation with universities and research institutions show that it is the positive external impacts which contributes significantly towards justifying research support.
- For over 40 % of the projects, it appears that the selective support for the companies (and the research institutions with which they collaborate) is fully exploited (full input additionality), while large parts of the benefits of a programme's combined portfolio come from projects with lower additionality.

Where publicly directed (user-directed) research programmes contribute to the initiation of projects which would not otherwise have been realised, and where full input additionality is achieved with this research support, the argument put forward in international specialist literature, that low average benefits is the main objection to selective support, is weakened (Hervik 2004). When the profitability of the marginal R&D projects is measured, as in the Norwegian studies, the way additionality works is clearly identified.

Another central tradition in studies of the impact of research is known as the study of "knowledge/research utilization" and studies the way in which research is used by players outside the research field, particularly within public administration. An important insight from this tradition is that the influential power of the research is underestimated if the focus is exclusively on directly measurable impact. Weiss (1980) notes that research results go hand in hand with the decision makers' prior experience and their access to information.

Research application is often divided into the following main categories (Amara et al 2004):

a Instrumental: as a direct basis for practical decisions, to solve clearly defined problems
b Conceptual: general information, diffuse and indirect use as intellectual ”background information”, that influence ways of thinking and concept formation.
c Symbolic: to provide support for one's own viewpoints.

The first and last form of research applications are fairly intuitively comprehensible, while conceptual use can cover a number of diverse and unrelated forms of applications of research, that can still be of decisive significance for the impact of research:

> *”to understand the background and context of program operation, stimulate review of policy, focus attention on neglected issues, provide new understanding of the causes of social problems, clarify their own thinking, reorder priorities, make sense of what they have been doing, offer ideas for future directions, reduce uncertainties, create new uncertainties and provoke rethinking of taken-for-granted assumptions, justify actions, support positions, persuade others, and provide a sense of how the world works.”*
> (Weiss and Bucuvalas 1980)

The three ways of using research must be understood as complementary and not as mutually exclusive. Different types of research results will have different applications in different types of environments and settings. The most direct benefit of research can occur where users apply the research-based knowledge base with the aim of obtaining / buying knowledge though project co-operation, through increasing knowledge and training personnel. One essential prerequisite is that researchers and the research institutions have sufficient quality, ability/ willingness to contribute, so that the users find that the benefit is greater than the costs.

Public players will have incentives to apply new knowledge through political decisions to reduce the number of accidents and injuries, while private players will use market-based considerations as a basis for their decisions to develop new and better safety related products and services. The public players will implement new research based measures through laws, guidelines, better planning, demands for better materials and equipment etc. The private players will develop new research based products or services.

All measures directed towards obtaining different forms of funding for research, from user- directed projects to basic research, and from individual projects to institutional support, are faced with incentive problems. Incentive problems arise in both the design of different measures and in their application. Evaluating innovation systems is intended primarily to measures impacts and efficiency, as well as studying whether incentives have developed across the whole innovation system which contribute to goal achievement to the greatest possible extent. Incentive theory provides an insight into the incentive problems that occur when research-political measures are applied, and how these problems can be met (See the relevant overview articles in Burgess and Metcalfe (1999), Pendergast (1999) and Gibbons (1998).

1.3 Methodological challenges

Determining the impacts of Swedish road safety research over 35 years is, as stated, almost impossible. Some specific challenges with this type of impact study include:

- *Positive impacts cannot always be documented.* At the national and social level a reduction in the risk of accidents, deaths and injuries will be natural impact indicators. There is little doubt that the development has been positive and that a number of effective road safety measures over time have contributed to an increasingly lower level of risk in Sweden. However, to determine exactly how much each individual measure has contributed is extremely complicated.
- *Research is not the only source of knowledge*. Knowledge that functions as a basis for road safety measures comes from numerous sources. A number of measures are carried out on the basis of an individual agency's experiences or political input (typically various campaigns). Here the role of research will be to evaluate the impact after implementation if possible by comparing with the situation before implementation.
- *Knowledge is a necessary but not sufficient condition.* If the impact of a measure are to be measured it needs to be put into practice. However, knowledge of an effective measure does not mean that it will be carried out in practice. This applies whether knowledge is acquired through research or in another way. It is not necessarily the quality and content of the research that decides its impact. This is also decided by a number of other social or industrial factors. Communication between research and decision makers is one important prerequisite for social research achieving an impact.

- *The kind of research/knowledge that has an impact changes over time.* When it is noted that the number of accidents is rising but the causes are not known, for example, there is probably a need for developing a fundamental understanding of the causal links (basic knowledge). Once knowledge of different causes has been obtained, testing how measures which can affect the causes, actually work in practice should have priority. And when the measures have been implemented, it is may be most important to study whether the measures are actually used as intended.
- *Knowledge that cannot be used directly can be important for more applied knowledge.* For example, good accident statistics and reporting routines cannot in themselves be said to prevent accidents, but are nonetheless necessary in making applied research more accurate.
- *Research that is not used can still be useful.* It is important for the funding bodies to identify measures that do NOT work, so that so that resources are not wasted. The challenge is that it is the nature of research that not all projects will produce results and that a number of factors influence the use of research results. It is also possible that a widening of the field, a steady demonstration of results over time can form the basis for the measures that are actually implemented. At the final stage it is a political responsibility to decide which safety measures should be adopted, but in order for this to be an informed choice, it is necessary to have knowledge about the choices which are to be discarded.
- *"Latent" research-based knowledge can prove essential for meting future needs.* Behavioural science traffic research in Sweden is a good example of the importance of having the means to develop institutions and knowledge in areas where at present there are no concrete opportunities for use, i.e. to have latent basic knowledge. Even though in recent years industry has not demanded this type of research, the need is becoming apparent now that new technology for guiding behaviour is being developed.

The above implies that it is not possible to create a complete and exact overview of all the impacts of Swedish road safety research. This also means that not all impacts can be measured in the same way. However, this does *not* mean that it is not possible to identify different types of links and impact chains. In this report we use different methods to indicate causal links between public resources used for road safety research, and different types of results. It is nonetheless important that the reader is aware that these descriptions cannot be complete and the fact the impact are not demonstrated in this analysis does not necessarily mean that the research has not been useful or without consequences.

1.4 Economic analyses combined with qualitative approaches

All the methodological approaches which can be used to determine economic or other returns from research, whether econometric analyses or surveys or case studies are used, have associated methodological problems. Econometric analyses are not particularly suited for determining the return of more specific support arrangements, such as the programmes that have supported road safety research in Sweden. They are unable show that in a support population there can be a few very successful projects that achieve exceptionally good results in the long term (possibly as late as after 10-20 years), while a majority of the projects will not normally be successful. The successful project results may often appear after a significant delay and often in somewhat surprising ways. The benefits of these can often justify the total costs for the entire programme. (Hervik et al 2005 and 2006). When the outcomes are of this nature, other methods must be used for analysis. Qualitative studies will give an insight into relations but will not bring out the size of the impacts and possibly not provide the arguments that are needed in the hard struggle for new funding.

Through a broad approach with the focus on some significant areas, it will nonetheless be possible in a valid manner to evaluate connections between the public economic focus on a research based road safety policy in Sweden and the reduction in the number of fatalities/ injuries which result from both public measures and a safety-directed manufacturing industry. Evolution of whiplash injury research at Chalmers demonstrated one possible way of carrying out such methodologically challenging studies (Eriksen et al 2004).

We will use a economic perspective in the impact analysis. From this, we can follow up additionality in a connected impact chain and quantify given parts of the benefit in kroner both for Swedish society and for the manufacturing industry and compare these with the costs. In this analysis we can show whether the values that have been created during the period studied exceed the costs. This type of historic cost-benefit analysis runs into many measurement problems and there are many impacts that fall outside the analysis but it does provide an indication of the size of the benefit of the research effort.

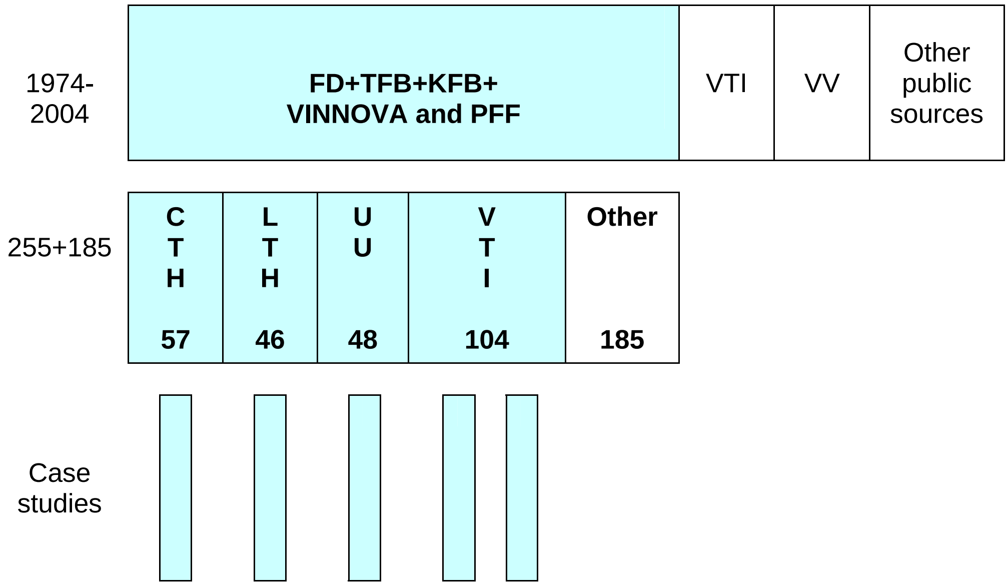
The benefit to society of effective protection against injuries comes in two parts. One is the benefit to the average citizen of the safety measures. The other is the gains to Swedish industry of increased exports of road safety products, or cars which contain these. The method for calculating the benefit to consumers builds on the same methodology as is used in cost-benefit analyses in the transport sector (Minken et al 2001). Here an attempt is made to measure the increased willingness to pay due to improvements in quality. This can be measured as a consumers' surplus in that we assume that the improvement in quality is not offset by a price increase in the Swedish market. In addition to the economic analysis, it is possible, with available data, to look at the benefit for Swedish industry by calculating the value of increased exports of the relevant products.

Use of knowledge occurs both directly and indirectly and with very different time spans. We have therefore focused on obtaining data on impacts that are difficult to measure, impacts where the value cannot easily be quantified and more diffuse transfer of knowledge or use of knowledge, and have used this in the projects reasoning. Besides, it is not certain that all benefits have been realised at the time the measurements were made. Thus anticipated future values must also be brought in either as figures or as arguments. In the private sector the value of a company cannot be set based on historic data but on the basis of future anticipated income. The anticipated income will often have to be based on historic data combined with more qualitative evaluations of the future. This has parallels with expectations of future impacts with regard to road safety in the historic economic analysis.

1.5 Broad spectrum of data to obtain a complete picture

In order to obtain a complete picture of the impact of the effort, we have evaluated impact at different levels. At the macro level a theoretical framework is used to study impact for society as a whole, while at the micro level we attempt to deepen understanding through the use of case studies of research institutions and research fields. By linking the different levels together we can better understand the mechanisms that have been significant for achieving success. Figure 1.2 illustrates the narrowing down of the whole area funded by VINNOVA and its predecessors and PFF, via studies of four central research environments, to focus on five case studies.

Figure 1.2. Gradual narrowing down of the focus of the study in order to describe the whole. Figures show funding from VINNOVA and its predecessors and PFF in the period 1974 – 2004,converted to values in the year 2000. The impact analysis covers the period 1971 – 2004, but in VINNOVA's project database there is no data for the years from 1971 to 1973. Both funding of research and other funding are included (ca SEK 12.7 million).



A broad spectrum of data exist as the basis for the analyses. These have been collected with the help of different social science methods. In addition to economic methods, we have used different forms of statistical analysis, including simple bibliometric calculations. We have also used traditional qualitative methods such as semi-structured interviews, group discussions and analysis of documents.

The analysis builds on a wide selection of sources;

- Riksdagspropositioner (Stortingsmeldinger), reviews, proposals and regulating letters (allocation letters) related to transport, research policies and industrial policies, including the restructuring of Swedish road safety research.
- Central transport- and safety policy EU documents.
- VINNOVA's database of all funded road safety research projects from 1974 to 2004. We do not have complete data for the whole period from 1971 and this means that we use somewhat different time periods for different parts of the analysis.
- Swedish accident data and analyses of the contribution of different factors to road safety.
- Written self evaluations of the research at four central institutions within Swedish road safety research with follow-up interviews

- Earlier peer reviews of Swedish road safety research related to topics and institutions respectively.
- Impact analyses of international publishing in general and also linked to special measures analysed in case studies.
- Research publications and other material related to five case studies of central research fields in the area of road safety.
- Interviews with representatives of important research institutions, sources of funding, users within the roads administration, municipal administration, the police, organisations, car-related industry, insurance and in the EU commission.

In order to obtain a fuller understanding of how people get ideas and how knowledge is generated and exchanged between different players, we have considered five examples or case studies. We have not considered all the measures that are important for Swedish road safety, but have tried to include cases that cover the different types of measures, different methodological approaches and work in each of the major institutions. We have also required that the impact on safety has been evaluated, i.e. that the impact chain is sufficiently well known for the benefit society to be identifiable. Furthermore we wanted the case studies, together with user interviews, to form the basis for investigating different mechanisms for impacts and different users' opinions of Swedish road safety research.

The five case studies are:

1. Speed reduction measures in towns/ cities, including constructing roundabouts (LTH)
2. Developing and standardising rearward facing child seats in cars (VTI and Chalmers)
3. Developing better protection against side impact injuries and whiplash injuries (Chalmers)
4. More effective police enforcement (Uppsala University and VTI)
5. Development and use of VTI's driving simulator (VTI)

The studies are described in more detail in separate documents, see Appendix 3-7. Arguments in the reports are also based on the previous impact analysis of neck injury research (Eriksen et al 2004).

2 Road safety trends 1970 – 2005

2.1 Road safety in a system perspective

In order to analyse the impact of Swedish road safety research we also need to understand the factors that are of significance for road safety and the development in the field. For a general discussion of this, see Elvik et al. (1997, chapters 3 and 4). The basis for this analysis is that road safety must be seen in a system perspective, i.e. that accidents occur as a result of a failure in the interaction between the three main elements in the traffic system; the road user, the vehicle and the road/ surroundings and between these again and the regulatory framework.

Nearly all road accidents depend in one way or another on road users' behaviour. A wrong action can occur as the result of an observational error, a decision error or failure to react (Treat 1980) or because the road user consciously or unconsciously chooses to compensate risk reducing measures with behaviour which increases the risk (Bjørnskau 1994, Vaa 2003). However, this does not mean that directing measures at road users is the most effective measure. It is also necessary to evaluate what leads to erroneous actions and risk compensation. On the basis of such knowledge, measures can be developed which can be targeted at the risk factors that can be affected.

Possible causes of accidents can be studied both statistically and qualitatively through in-depth analyses of accidents. Several analyses of this type have clearly shown that accidents and their consequences cannot be understood as the result of one single factor, but rather, as a rule, are due to a number of factors failing. Due to the high number of accidents in road traffic, statistical analyses can provide a picture of the factors which contribute to high accident figures and serious consequences of accidents.

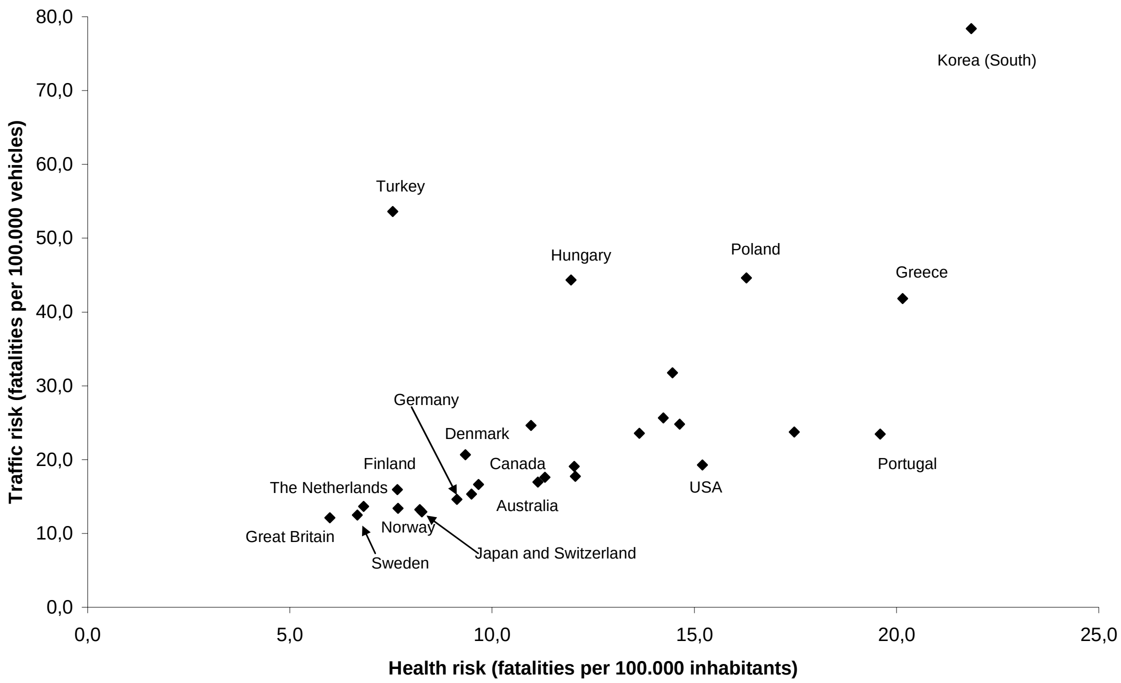
Key factors for the accident risk include traffic volume, travel mode, type of vehicle, design of the road system, weather and driving conditions, road-user characteristics (age, gender, state of health) and their behaviour. As for the severity of an accident, the vehicular mass, the level of protection, the speed at the time of the accident, road user characteristics (especially age) and use of personal safety equipment are all significant. The speed at which medical help is available is also important. (See Elvik et al 1997, chapter 3).

2.2 Sweden – one of the safest countries

The World Health Organisation defines road accidents as one of the world's largest health problems, estimated to become the third most important cause of death by 2020 (Murray and Lopez 1996). The are no exact or complete statistics on a global basis, but figures from WHO and Global Road Safety Partnership indicate that the annual number of fatalities may lie between 1- 1.5 million people. Using SIKA's (2005a) calculated value for a human life as SEK 17.5 million (2001-prices), it is easy to understand that measures that can reduce the risk in traffic have an enormous potential, both economically and to reduce human suffering.

Sweden has a very low traffic risk compared to many other countries. There are major differences between countries with regard to the traffic risk. Casual pathways are complicated and many players from different sectors of society are responsible for the development. A country's wealth, degree of motorisation, knowledge of measures and resources for preventing and limiting the impact of accidents all affect the risk. Figure 2.1 shows differences between the IRTAD-countries in 2000. A total of 125,000 people are killed annually in these highly motorised countries.

Figure 2.1: Health risk (fatalities per 100,000 inhabitants) and traffic risk (fatalities per 100,000 vehicles) in 2000 in countries that are members of IRTAD.



Source: IRTAD

2.3 Accidents cost about 30 billion SEK annually

The socio –economic costs of accidents are very high, see table 2.1. Using SIKA's evaluation (2001 prices) we see that the cost of fatalities in Sweden in 2005 can be calculated at almost 8 billion SEK.

To this should be added the number serious and minor injuries. Injury statistics are incomplete. Before STRADA[8] was set up, where data about injures is obtained from hospitals, the Central Bureau of Statistics in Sweden estimated that the percentage of injuries reported was 59 % for serious .and 32 % for minor injuries (SIKA 2005b). Using the accident figures for 2005 (SIKA 2006) this means that for each person killed in a traffic accident , another 15 will be seriously injured and about 160 will incur minor injuries. In our calculations we have used a ratio of 10 serious injuries and 100 minor injuries for every traffic fatality in order not to overestimate the numbers injured. This gives a total annual accident cost of about SEK 30 billion.

Table 2.1: Numbers killed and injured in Swedish road accidents in 2005 together with an estimate of the costs based on SIKA's evaluation (2001-prices). In million SEK

Severity	Annual total for 2005	Cost per injury	Social cost
Fatalities	440	17.50	7 700
Serious injuries	4 400	3.12	13 700
Minor injuries	44 000	0.18	7 900
Total			**29 300**

Serious injuries comprise broken limbs, being crushed, serious cuts, concussion or internal injuries. In addition, anyone who is admitted to hospital is regarded as seriously injured. All other injuries are classified as minor injuries. These definitions are used by the police when reporting accidents involving injuries (SIKA 2005b, Vägtrafikskador 2004, page 69). Work is being carried out to develop more precise definitions of injuries.

2.4 Traffic safety development in Sweden overall

The number of fatalities and injuries in Sweden have gone down dramatically in recent years, see figure 2.2. In 1970, 1307 people died in road accidents. In 2005 the figure was 440, a reduction of about 66 %. Fatalities which are presumed to be due to acute illness triggering an accident are not

[8] New Swedish system for road and traffic data where both police and hospital data are used for accidents. The introduction of STRADA has probably increased the degree of reporting, especially for minor injuries

included in this figure.[9] Sweden has achieved this reduction despite the fact that the number of kilometres driven doubled from 37 to 77 billion vehicle kilometres annually in this period, see figure 2.4. From 1970 the numbers killed in traffic have gone down in a number countries, but the trend in Sweden has been more favourable than in Norway or the USA for example.

In figure 2.2 a trend line has been included which shows an annual decrease in the numbers killed of 2.9 %. A 95 % confidence interval around this trend line is also shown. It can be seen that the decrease in the number of fatalities has not been entirely uniform. Periods with stagnation or a temporary increase in the number of fatalities have occurred. Explanations for these variations, which are mostly random, are outside the scope of this analysis. The trend line shows the systematic improvements in road safety from a fitted value of fatalities of 1258 in 1970 to 454 in 2005. In chapter 7 we will return to the individual causes of this systematic trend.

Figure 2.2: Changes in the numbers killed in road traffic in Sweden 1970-2005

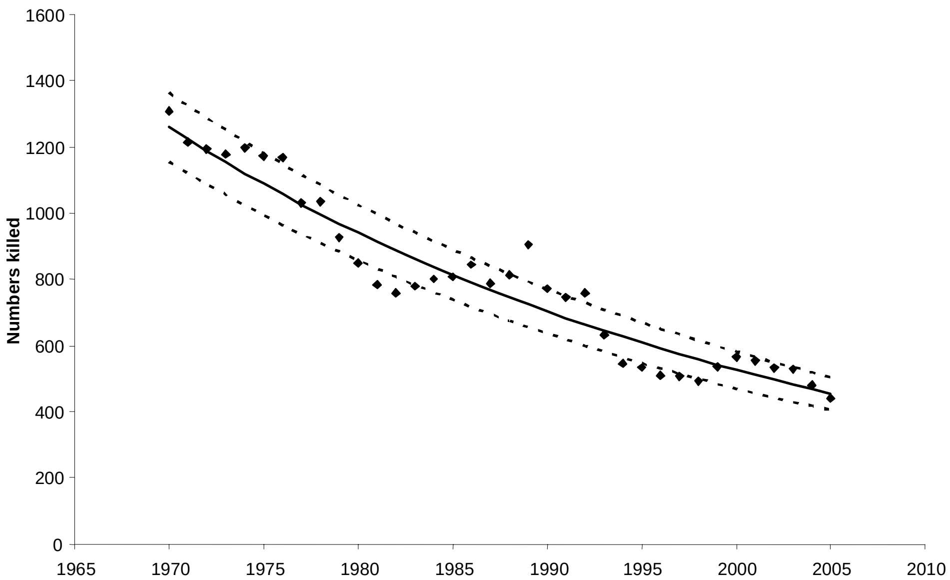
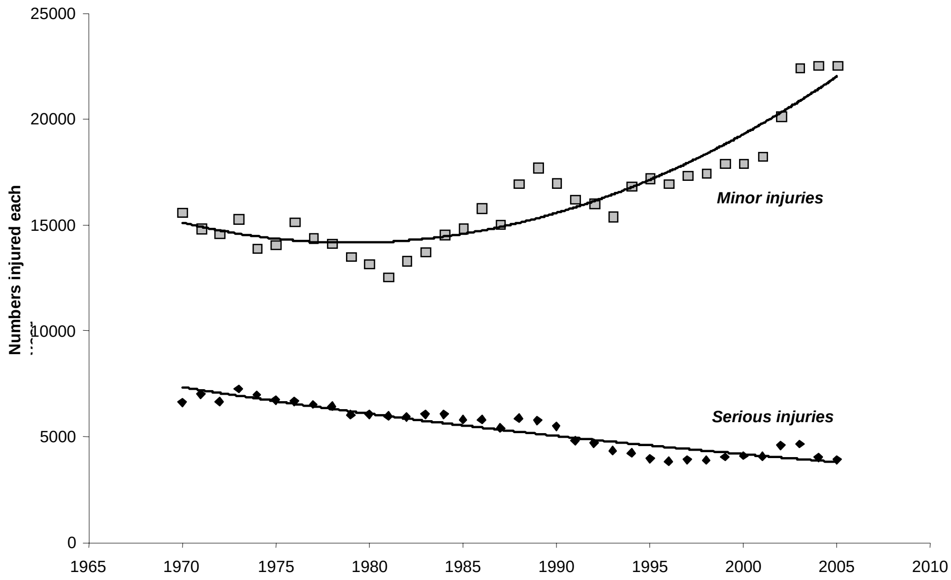


Figure 2.3 shows similar changes from 1970 to 2005 in the number of serious and minor injuries respectively. The trend line which is fitted to the points representing the number of serious injuries in figure 2.3 shows an average annual decrease of 1.9 %. The decrease was evident up 1995. The number of minor injuries has increased, particularly in recent years, which may be due in part to better reporting of minor injuries. The trend line for

[9] For example, this applies to heart attacks which lead to accidents. What is included in the figure for the different years is significant when measuring the degree to which specific goals have been achieved. This forms part of a discussion in Sweden in connection with sub goals for Vision Zero.

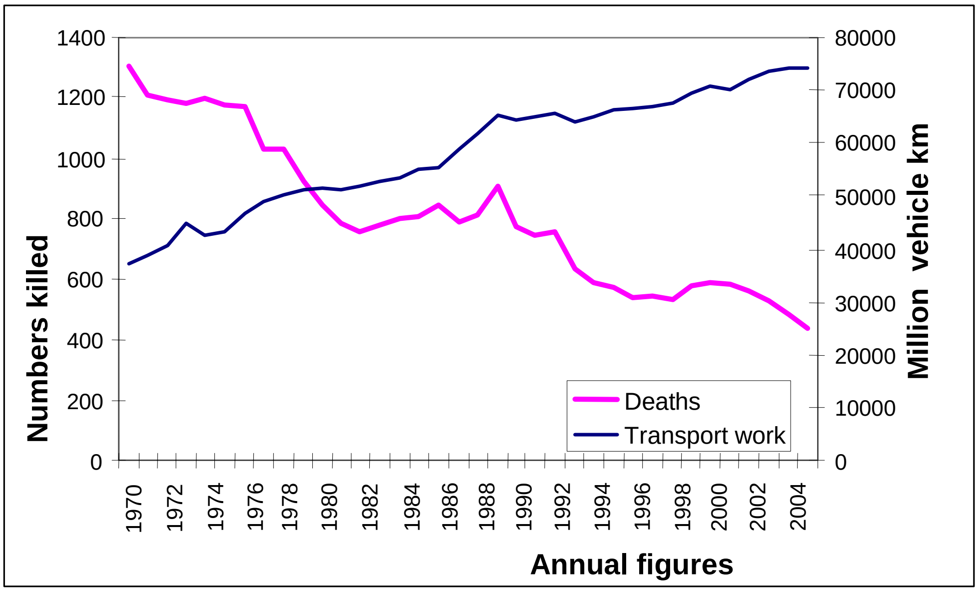
minor injuries is a second-degree polynomial which shows a progressive increase toward the end of the period.

Figure 2.3: Changes in the numbers of serious/ minor injuries in road traffic in Sweden 1970-2005



From 1970 to 2005 road traffic has more than doubled, calculated in million vehicle kilometres. All other conditions being equal, increased traffic means an increase in the numbers injured or killed in traffic. Thus there is no doubt that road traffic in Sweden has become considerably safer during the last 35 years. An important background for understanding that this progress has required a large effort, is that the number accidents and their severity have been substantially reduced in a period with strong growth in car traffic, see figure 2.4. Road traffic has increased by a little over 100 % from 1970 to 2005 – the risk of being injured or killed has accordingly been reduced, the risk of minor injuries as well.

Figure 2.4: Trends in the number of fatalities and the number of vehicle kilometres in Sweden in the period 1970-2005.

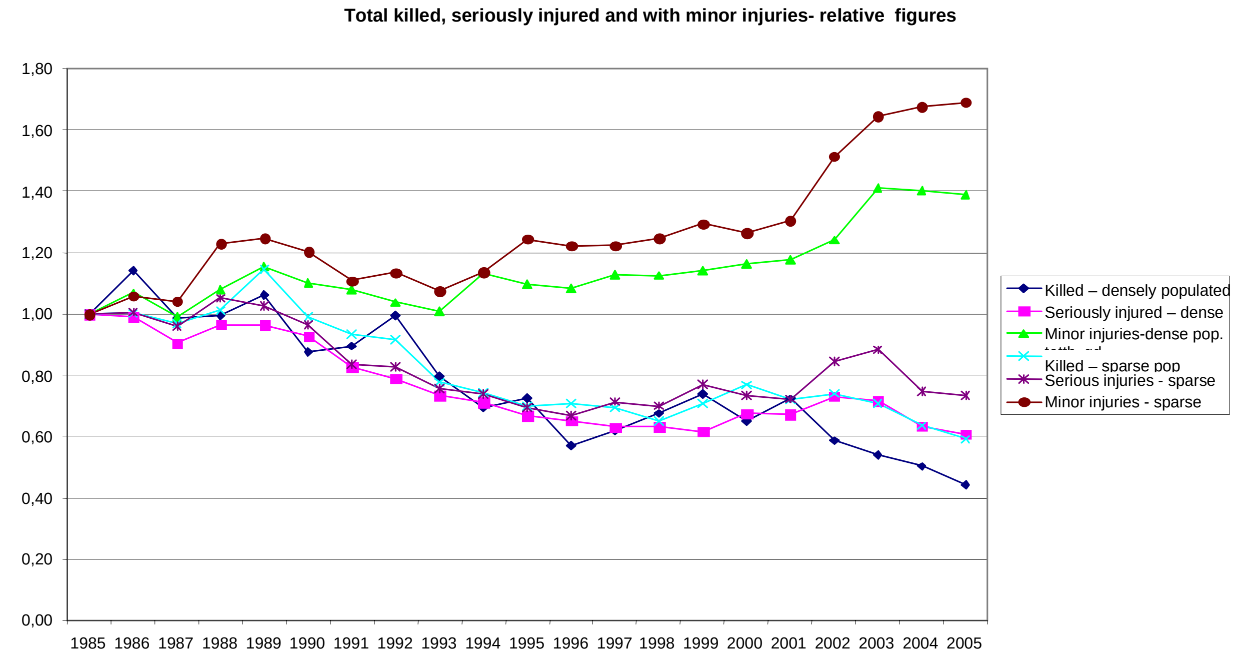


Source: SIKA, VTI and Vägverket

2.5 Trends in different areas and for different road user groups

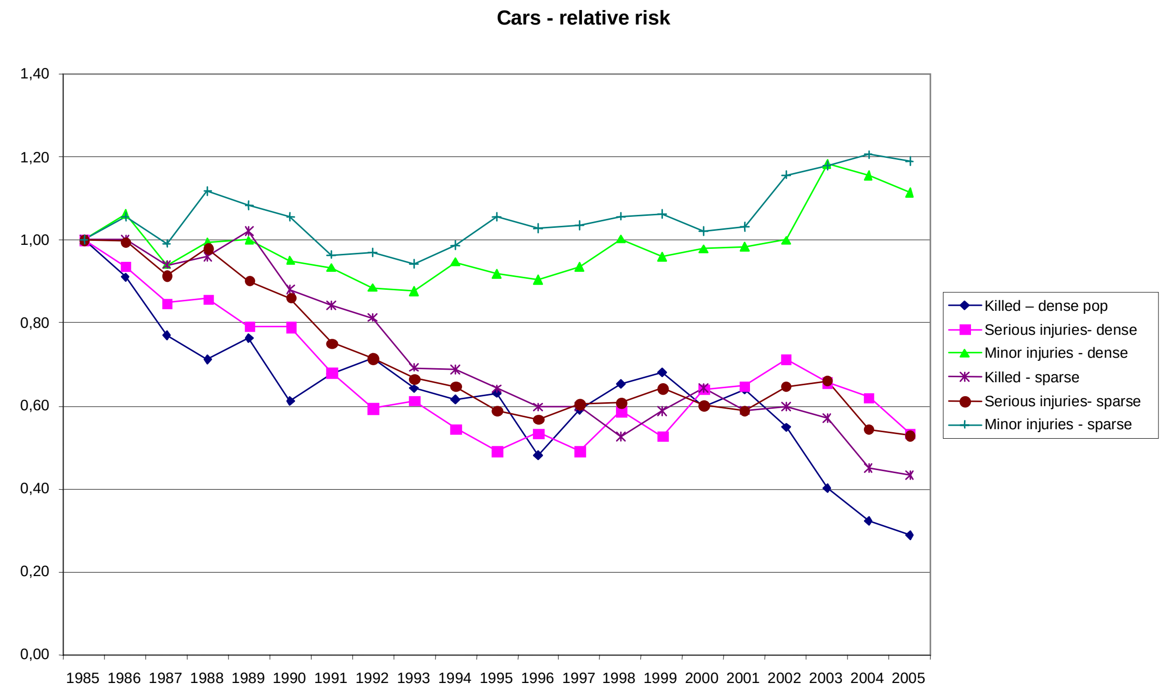
We have also carried out more detailed analyses of the trend in the period 1985-2005, to investigate whether the changes have been different for different groups and whether there are differences between town and countryside. The analyses show that the numbers killed and seriously injured have been reduced for all road user groups. This applies independently of population density. In a macro perspective there is little difference in the development between densely and sparsely built-up areas. (Skedsmo 2006), see figure 2.5.

Figure 2.5: The trend relative to 1985 (1985=1.0) in the numbers killed, seriously injured and with minor injuries in Swedish traffic in the period 1985 to 2005, densely and sparsely built-up areas.



Source: SIKA's database

Figure 2.6: The trend relatively to 1985 (1985=1.0) in the risk of being killed, seriously injured or incurring minor injuries as a car user (drivers and passengers), distributed over dense and sparsely populated areas.



Source: SIKA's database

2.6 Summary

All in all, road safety in Sweden improved considerably in the period covered by the impact analysis, that is, from 1970 – 2005, and injury accidents have become less serious. The main trends in the development can be summarised as follows:

1. The number of fatalities went down by about 67 % from 1970 to 2005.
2. The number of serious injuries went down by about 45 % from 1970 to 2005.
3. The number of minor injuries has increased by about 60 % from 1970 to 2005.
4. Road traffic has increased by a little over 100 % from 1970 to 2005 – the risk of being killed or injured has been reduced, including minor injuries.
5. The proportion of all killed and injured that were killed has gone down from more than 5 % in 1970 to less than 2 % in 2005.
6. The proportion of all injured and killed who were seriously injured has gone down from about 35 % in 1970 to about 16 % in 2005.
7. The risk of being killed in traffic in Sweden has gone down by over 80 % from 1970 to 2005, while the risk of being injured has gone down by about 50 %. In other words, road users are now travelling more safely than before.

The Swedish society has set up various subtargets within Vision Zero. One of these subtargets is that the numbers killed in 2007 should be down to half what they were in 1996 (Riksdagproposition 2005/06:160). This corresponds to around 270 people in 2007. The figures we have presented may indicate that it will take some years before this target is achieved. However, the trend is in the right direction, and a downward trend must be regarded as a success considering the powerful increase in the amount of traffic from 1970 – 2005. The economic costs of traffic injuries in Sweden –based SIKA’s valuations - amount to SEK 30 billion annually.

3 Swedish Traffic safety research 1970 – 2004

3.1 Sweden has focused on road safety research

One condition for being able to utilise research is that society understands the benefit of increasing knowledge. Right from the 1930s, Sweden has been acquiring knowledge about the causes of road accidents in order to develop measures to prevent such accidents. It was the question of road safety which was the very beginning of the focus on transport research. In 1948 the *1945 road safety committee* proposed setting up a separate governmental body, ”Kungliga Trafiksäkerhetsstyrelsen”, and said:

> *”Given that that the road safety committee's work to a large extent has to build on research, it is highly important that the head, even if he is not an academic ,is capable of understanding the significance of the research and assimilating its results.”*
>
> (Englund 2000a, p. 7)

In fact no governmental body was set up at that time, but the understanding of the importance of research formed the basis for substantial governmental funding for Swedish road safety research. One expression of Swedish society's emphasis on knowledge is the many committees and reviews at a high political level which through the years have been given the task of evaluating society's management of knowledge production in the field of road safety. A line runs from the 1945 road safety committee to the review entitled ”*Transportforskning i en föränderlig värld*” (“Transport research in a changing world”) (Wijkmark 2004) which Riksdagens trafikutskott commissioned in 2004, and which had the mandate to investigate the effects of the re-organisation of research funding in 2001.

A German benchmark study of European research also highlights the applied research approach, i.e. the connection between research and social and market values in its main conclusion regarding Swedish research;

> *”Swedish transport research is relatively well organized; attached to clear, ambitious political targets; market oriented, practical, and pragmatic. It is also well funded and well staffed. The objectives of this research are defined by the policy-making community and by society…..”*
>
> (Borcherding 2004, p. 108)

3.2 A separate funding body for road safety or transport research for 50 years

Road safety research is mainly applied research targeted towards one sector – the transport sector. Traffic safety research can and must be based on the basic research that is carried out at the universities, and which can also contribute in some cases to produce basic knowledge in a field. Nonetheless, sector research requires separate funding systems. Swedish road safety researchers consider it as unthinkable that they should receive funding from Vetenskapsrådet or other scientifically-based research councils. Swedish society has taken this seriously.

Traffic safety research in Sweden from 1949 - 1971 was was dependent on a separate road safety related funding body: The National Road Safety Council. This funded two research laboratories and five scientific posts as well as external research. A separate working group – TRAG – focused on the compilation of accident statistics and studied the effect of speed limits. Work in this period provided a number of important results, as indicated by the following quotations from the Secretary of Trafiksäkerhetsrådet;

- *”Guidelines for teaching children how to behave in traffic (this research has uncovered significant errors and omissions in previous teaching guidelines)*[10]
- *Recommendations for traffic-safe behaviour in the dark.*
- *Rules for restructuring and planning and building communities from a road safety point of view*[11]*.*
- *Norms for personal protection for car users (for example, safety belts and crash helmets).*
- *Demonstrating the value of local speed limits.”*
  (Englund 2005)

The work formed a good basis for the research topics that were followed up from 1971, i.e. the period we are looking at in this impact analysis. For example, the medical research laboratory was the predecessor for both the biodynamic research at TTS (gruppen för tillämpad trafiksäkerhetsforskning at Chalmers) and VTI’s work on child restraints in cars and the design of posts along roadsides. The first rearward facing child seat was presented as early as 1964, see Appendix 4.

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[10] This was the result of the work at the Child Psychology Research Laboratory (Barnspykologiska forskningslaboratoriet).

[11] The SCAFT-principles, ie the principles of separating vehicular traffic and soft road users as well as building up a hierarchy of roads with footpaths closest to houses.

In the transport research review of 1964, in view of the importance of transport in society, it was argued that funding for transport research should be concentrated in a single body. From 1971 the new Transportforskningsdelegationen (TFD) was given responsibility for co-ordinating research funding in the field. The previous Trafiksäkerhetsrådets own research tasks were given to a new and expanded VTI (Statens Väg- och trafikinstitut), to Chalmers and to Uppsala University. From the early 1970s, Lund University (LTH), which developed the research field of safety in towns, was also an important institution. These institutions are described in greater details in chapter 4.

In 1988 TFD merged with Kollektivtrafikberedningen to form Swedish Transport Research Board (TFB). In TFB road safety research was dealt with in three programmes; ”Driver information processing”, ”Speed problems” and ”Unprotected road users”. In 1993 TFB became The Swedish Transport and Communications Research Board (KFB). KFB had a different organisation to TFB and focused on multi-year thematic programmes that were defined through dialogue with research institutions. This was a form of organisation that was appreciated by the research community.

3.3 From research to innovation –a new organisation from 2001

In recent years the desire for links between industry and research has become more explicitly expressed in research and industrial politics. There is an international trend for public research funding to be used to achieve industrial -political aims for innovation and to stimulate growth in industry, and this also includes transport and road safety research, according to the Government’s (2005a) strategy *”Fordonsindustrien – en del av det Innovative Sweden”(“Vehicle manufactering –a part of the innovative Sweden”)*[12]. On the basis of this a decision was made for KFB to be closed down from 1.1.2001.

The responsibility for funding parts of the transport and road safety research was then transferred to a separate section within VINNOVA that will focus

[12] A quotation from the Government’s (2005a) strategy: ”Fordonsindustrin – en del av Innovative Sweden” can illustrate one way of thinking; ” *Developing the conditions for innovation and strengthening the innovation climate are crucial if Sweden is to be successful in the increasingly difficult international competition. The role of the car industry is significant because it represents roughly a fifth of employment within the manufacturing industry and contributes to a significant proportion of the research carried out by companies, universities and research institution. The development of the car industry and car technology is crucial not only for trade policy and employment policy goals, but also for attaining ambitious goals for transport, environmental, regional and energy policies.”*

more on technical and industry-directed problems. VINNOVA – the agency for innovative systems, is a Swedish governmental authority[13] which has the responsibility for: *"promoting the growth of Swedish innovation systems in the areas of technology, transport, communication and work."*

VINNOVA was established on 1 January 2001, partly through the merger and restructuring of several public bodies, in order to promote technology-related research, in addition to KFB and the technical section of NUTEK (Verket för näringsutveckling). The purpose of the restructuring was to stimulate more dynamic cooperation between researchers, sources of funding and users.

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VINNOVA has different instruments to support research, including;

- *Growth areas* where work is on Innovative vehicles, vessels and systems together with Innovative logistic systems and goods transport.
- *Knowledge platforms*, where the focus is on Infrastructure and innovative transport systems.
- *Centre of Excellence* (VINN Excellence Center). This type of road safety related centre (SAFER) is being developed in Gothenburg linked to Chalmers and the car industry's road safety research.
- VINNVÄXT are regional innovation systems that can include research institutions, industry, organisation and public enterprises.

With the disbandment of KFB there is no longer one single source of funding or authority with all-encompassing responsibility for the long-term development of knowledge in the field of road safety research. This change in a fifty year old sector research tradition has caused concern in Swedish research institutions, see section 4.6, and is being discussed by the Swedish Parliament (Wijkmark 2005). These concerns are particularly strong when it comes to the responsibility for more applied society-directed road safety research and also road user-related research.

Responsibility is now shared between VINNOVA and Vägverket, and it is clear that they are responsible for the long term and for coordination. How-

[13] VINNOVA would in Norway partly corresponds to the Norwegian Research Council's Innovation Division

ever detailed information is not available about the responsibility for specific themes or research areas in the regulating documents, strategies or in any other way. VINNOVAs responsibly covers national coordination of transport research which takes place through TRANSAM in which approximately 10 involved authorities participate. VINNOVA's activity within the area of transport will:

> *”develop the transport system so that it promotes sustainable growth and contributes to the realisation of all the transport policy goals.”*
> (VINNOVA 2005).

In the most recent report from the Swedish government ”Moderna transporter” from 2005/2006 (Riksdagprp 2005/06;160) the sector responsibility for research is emphasised and this also implies responsibility for long term research:

> *”Sector research is not just a question of solving immediate problems but shall also contribute to prepare for challenges that are not yet known. The responsibility for ensuring future research competence and qualified research institutions with the expertise in relevant fields also lies with sector research. As previously, the government is of the opinion that R&D will be ever more important for the evolvement of a sustainable and efficient transport system”*
> (p. 134)

3.4 PFF – a new model for linking industry and research

Some areas of Swedish road safety research have been linked to and supported by industry for decades, for example the development of cars and equipment for protection against whiplash (Eriksen et al 2004), safety equipment for passengers etc. In 1994 a separate research funding body, PFF, was set up for interaction between industry and research as:

> *”…the aim to strengthen the competitiveness of the Swedish car industry. This can be done by funding vehicle technology research within the areas of safety, the environment and cost/ quality. t.”*
> (PFF 2005)

The programme is funded 50/50 by the state and the vehicle industry, the state providing funding for the research institution and industry contributing time and equipment. This gives these ventures some influence on the projects that are initiated. Industry provides for project support but is expected to collaborate with universities or polytechnics. Today PFF has four programmes, of which two are clearly related to safety; Fordonsforskningsprogrammet (ffp) (The vehicle research programme) and the Intelligent Vehicle Safety System-programme (IVSS).

VINNOVA acts as the secretariat for the Programrådet for fordonsforskning (PFF).

The PFF programme (the ffp-section) has been evaluated twice, both times with good results (see www.pff.nu). It is concluded that the projects have been relevant for research, for industry and for society and have contributed to long-term research of value for the manufacturing industry. Safety related themes funded by PFF are whiplash research, injuries to the lower extremities, heavy vehicle stability, child safety in cars and drivers' mental stress.

3.5 Large public resources for road safety research

Following the Second World War, substantial public research funding (defined here as funding from governmental bodies whose main responsibility is to fund research) was granted to Swedish road safety research. We do not have any price-adjusted figures from Trafiksäkerhetsrådets 23-year lifetime (1949 – 1971), but since 1971 TFD, TFB/KFB, VINNOVA and PFF have granted some SEK 440 million, see table 3.1. In total this form of public funding for safety research probably amounts to around half a billion SEK

Table 3.1: Road safety research funding from TFD, TFB/KFB, VINNOVA and PFF (funding for the ffp section only included) from 1974 -2004, all funding. (Years denote start up year for the activities) Number of projects and total funding in SEK 1000 year 2000 prices)

Source of funding	Total funding 1000 SEK	Number of projects	Annual Budgets Mill SEK
Transportforskningdelegationen, TFD (1971-1984)	101 830	112	4.6-11.0
Swedish Transport Research Board, TFB (1984-1993) and The Swedish Transport and Communications Board, KFB (1993-2000)	232 535	279	13.0
VINNOVA (2001 – 2004)	33 298	13	10.3
Programmet för fordonsforskning, PFF (1994-2004)	60 577	30	8.4
TOTAL research projects	**427 800**	**434**	
Other projects (teaching, jobs, travel – all in TFB/KFB)	12 700	39	
TOTAL	**440 500**	**473**	

The budget for pure public road safety research have been somewhat reduced by the restructuring. Englund's (2000) overview of the areas funded by TFB from 1985-1992 show that road safety research's annual budget in constant prices increased up until 1991 (from 4.6 – 11.0 mill SEK). With KFB, funds for road safety research increased to SEK 13 million annually. VINNOVA granted SEK 10.3 million annually for the budget years 2002-2004, i.e. the annual budget has gone down somewhat in recent years. From 1994 additional funding came from PFF, with an average of SEK 8.4 million annually, firstly to KFB and then to VINNOVA's budget.

The figures in table 3.1 do not include co-funding from other sources. To inform of co-funding was not required for TFD, TFB or KFB-projects and despite the fact that projects received funding from several sources,this is not shown in the applications or the accounts. VINNOVA normally requires projects to be co-funded by industry, organisations or the public authorities. The purpose is to develop networks and to create a good basis for applying the research. Projects from PFF require 50 % part funding from private companies, which gives such companies influence over the projects which are to be implemented. This funding comes in addition to the budgets shown here.

Vägverket is a major agent within the field and has funded research and also contributed to the development of research institutions through a separate departmental programme and -funding from both central and regional departments in the organisation. It also administers the Skyltfonden (The number plate fund) [14]. Vägverkets R&D budget for the period 2002 - 2004 (Vägverket 2003) included SEK 48 million for road safety research, a sum that exceeds VINNOVA's funding for the same period. It is not known whether the whole budget was allocated for research. Other sector agencies which have contributed are The Road Traffic Inspectorate and the former The Swedish Road Safety Office, which played an important role both through its own research and through research funding (1968-1993).

Other public research funding bodies have also contributed to Swedish road safety research, particularly the EU's framework programmes in recent years. To this should be added public funding granted as fundamental funding from the Ministries to universities and research institutions. Furthermore, Swedish road safety research has received large monies from organisations and from industry and insurance companies.

We have not been able to collect information on funding from other sources in detail. In Chapter 4, where we describe four central research institutions

[14] R&D funding from payment for personalised number plates.

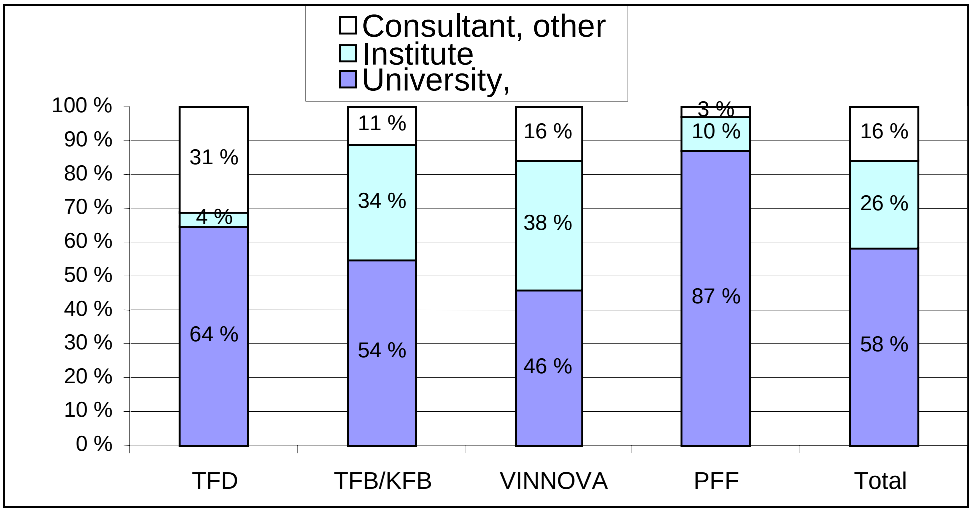
working in the safety field, some rough figures are given for funding from different sources. These can illustrate the relative importance that VINNOVA and its predecessors and PFF have had from a financial perspective,

3.6 Universities and institutions have received the greater part

Developing strong research institutions is a primary aim and a first order impact of the funding. These institutions can, when they are fully qualified, later obtain research funds from other agents independently of the funding bodies that contributed to their development.Vigorous research environments also contribute – alongside their own knowledge-expanding activities – to making international research activities both known and applicable within a national context.

The lion's share of the funding (here measured as the share of projects) from VINNOVA and its predecessors and PFF has gone primarily to the university and polytechnic institutes and to a certain extent to research institutions. These account for 58 % and 26 % of the projects respectively, making a total of 84 %, see figure 3.1. The large increase to institutions (read VTI) which occurred after TFD was closed down goes hand in hand with changes in VTI's funding at the same time.

Figure 3.1: Proportion of projects allocated to different types of active institutions from TFD, TFB, KFB, VINNOVA and PFF [15] in the period 1974 - 2004. All projects, (N= 478). Percentage.



[15] For all projects under PFF and several under VINNOVA , the car industry is the applicant, while the active instituion is a university. Here this is coded as UogH.

When, as in Sweden, the aim is to get the university environments to play a vital role within sector research, it is important to stimulate work towards a desired thematic content within the research discipline. With support from TFD, TFB, and KFB four strong specialist institutions important for Swedish road safety research were developed from the 1970s onwards. They are also important for the education and development of road safety expertise in Swedish society. Three of the institutes are based at universities or polytechnics. These are: the Department of Applied Traffic Safety (formerly TTS/Personskadeprevention) at Chalmers Technical University (CTH), the Department of Technology and Society at Lund University (LTH), the Department of Psychology at Uppsala University and the Swedish National Road and Transport Research Institute (VTI). These four represent well over half the (59 %) number of projects and 60 % of funding within this period, see table 3.2. VTI and Chalmers have also been supported by PFF and VINNOVA.

Table 3.2: The four major institutions' research projects in the period 1974- 2004 by source of funding, total number and total funding in SEK 1000

Institution	TFD	TFB/KFB	VINNOVA	PFF	Total number	Funding 1000 SEK
Chalmers, TTS[16]	5	15	2	12	34	56 772
LTH Tekn ok samh,	19	43			62	47 409
Uppsala University, Psykologi	25	29			54	47 831
VTI	4	94	4	3	105	102 740
Total for the four major institutions	53	181	6	15	255	254 752
Total from source	112	279	13	30	434	427 300
Proportion to the four major institutions	47 %	65 %	46 %	50 %	59 %	60 %

The remainder of the funding is distributed relatively widely across a total of 105 institutions. The project database contains 434 research projects in total of which the four largest research institutes have been the recipients of 255. Amongst the other institutions, six specialist institutes have received five or more projects. These comprise a total of 40 projects (9 %). Otherwise some 50 environments have been allocated between two and four projects and a further 50 or so have each been allocated one project.

[16] One project for SAFER could pssibly have been included here, but this has not been done.

The institutions with five or more projects are also well-known research institutions, but tend to have a focus other than road safety research. As a rule they will have worked with road safety for a shorter period than the four main institutions:

- Institutionen för stadsbyggnad at Chalmers which worked on traffic planning in cities in the period 1974-1977. (5 projects)
- Institutionen för farkostteknik ved Kungliga tekniska högskolan (KTH) worked on safety in heavy vehicles in 1992-2002. The car industry was the applicant (5 projects)
- The Department of Mathematics at the University of Linköping worked on statistical methods and models related to safety from 1982-1999. (6 projects)
- The Department of Psychology at the University of Lund took over the field of Children in traffic for the period 1996-1999. (5 projects)
- Transportforskningskommisionen (TFK), a company that has been supported during the whole period, primarily in IT and industrial transport (10 projects)
- TOS AB, a company that was linked to the psychology department at the University of Uppsala. During the period 1977 – 1984 it worked on speeding and measures against speeding (9 projects)

The creation of groups of experts is an important impact of research funding, and a fundamental element in the impact chain that ensures that expertise is upheld and utilised. This does not mean that individual efforts may not also be of major significance, even though they have not resulted in a permanent group of experts. Individual projects at university institutions may act as an opening for new PhD projects and thus contribute both to the achievement of academic merit and to spreading understanding of road safety. Amongst the institutions that have taken on one project, a number of project leaders can be noted who have served as project leaders for projects for other institutions. This may indicate formal collaboration (for example a professor II post) or that researchers who have worked on road safety in smaller research groups are linked to the larger institutions later in their careers.

Traffic safety research at smaller institutions has often been carried out in collaboration with major subject institutes, for example statistical research at institutes of mathematics to support more applied research. It is also possible to talk about cluster impact when different environments collaborate. Collaboration with the Big Four can be seen as a contribution to the research of both institutions.

Part of the reasons behind KFB becoming VINNOVA was an industry and research-based need to concentrate the Swedish effort to ensure participation in the international market. Table 3.2 indicates that a change is now occurring in the allocation of projects. It appears that the dispersal to many small institutions has been reduced. VINNOVA's funding goes to Chalmers, VTI or to specialist institutions in the middle group with five to ten projects. The road safety research institutes in Lund (LTH) and Uppsala (Department of Psychology) have so far not received any funding for projects from VINNOVA. The long-term impact of this are beyond the time span of this analysis, but we will return to the institutions views of the constraints on funds in chapter 5.

3.7 Changes in perspective and thematic focus during the period

Right from the start, Swedish road safety research has had an impressive breadth. Statens trafiksäkerhetsråd's proposal for research topics covered most fields where research is still being carried out and funding over the years has been granted to specialists from a number of fields and to institutions with experts from many fields such as VTI. Even though individual specialist groups at the universities have been from within one field, the combined contribution has clearly been interdisciplinary.

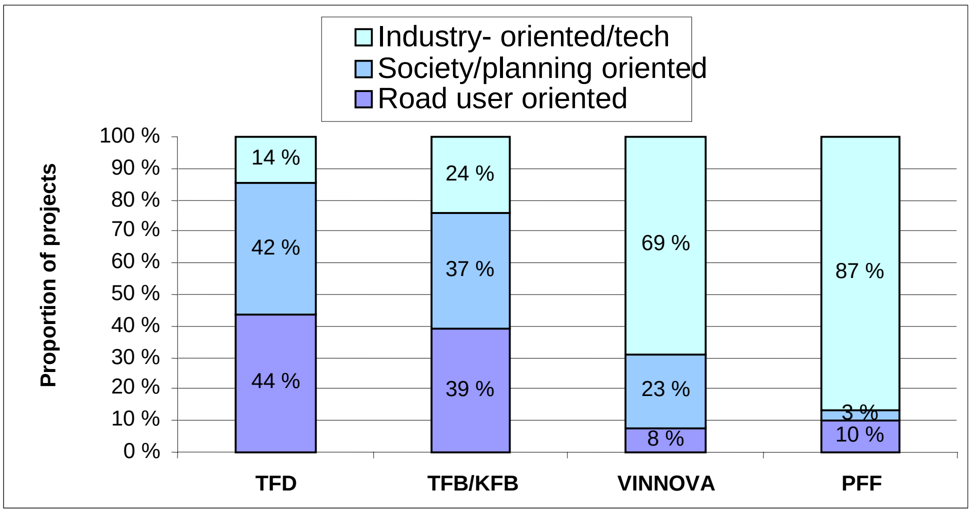
After KFB was closed down, several research institutions, as well as the Riksdagens trafikutskott (Wijkmark 2004), have expressed concern that the prospects of society-directed research has worsened. Society-directed research is taken to mean research directed at road users and research that can provide a foundation for public planning and work on measures. We have categorised the projects in VINNOVA's database in three main groups:

- *Society-directed research* which covers accident costs, charting situations, social evaluations, cost/ benefit analyses, road planning, road design and road equipment, as well as planning at the local level.
- *Road user-directed research* covers basis knowledge about behaviour, impact of measures to regulate behaviour and teaching-related development of expertise in the field.
- *Industry-directed and/ or technical research* which covers technology and vehicle development, biomechanics and associated activities as well as IT projects.

There are no clear dividing lines between the various categories. It is particularly difficult to distinguish road user directed research from the others. Firstly, most road safety research is ultimately targeted at making road users safer, and secondly, basic research into features and characteristics of road users can be used in both society- and industry directed research. Thirdly, projects may belong to several groups, for example, a project that looks at the relation between road design and behaviour could be both a road- and a road user directed project. We have categorised the projects according to what we considered the main focus.

The picture is relatively unambiguous, see figure 3.2. There is less focus on society–directed and road user directed projects in VINNOVA's portfolio than there was in TFB/KFB. This is in line with the reason for transferring KFB's funding and parts of its responsibilities to VINNOVA. The goal was to direct the technical and industry oriented research, an goal that VINNOVA has achieved. In PFF too the focus is – naturally enough for a vehicle technology programme- on technical research. Both these agents have given considerable financial support to the work on different forms of passive safety in cars based on collaboration between experts from various fields.

Figure 3.2: Projects financed by TFD, TFB/KFB, VINNOVA or PFF in the period 1974-2004 according to theme. Proportion of research projects (N=431)



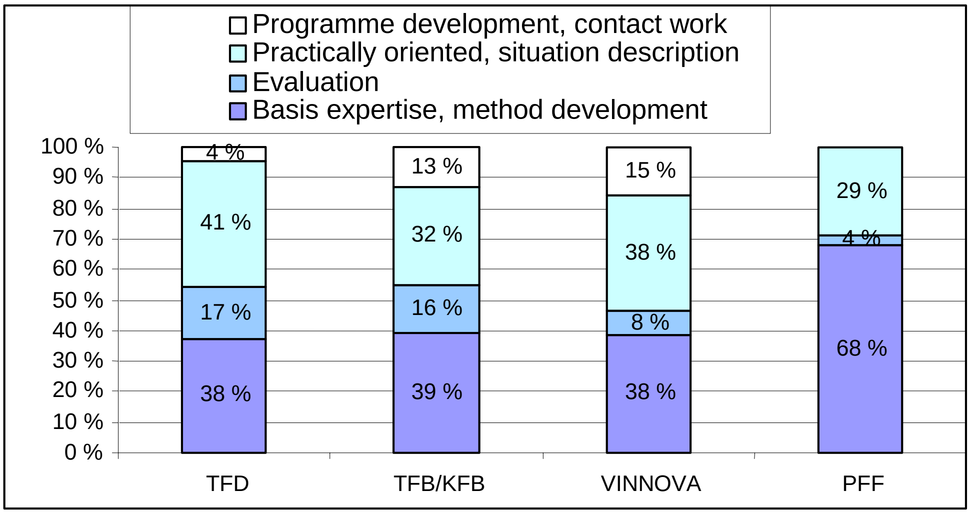
Transport research or road safety research is sector research and as such is clearly based on potential applications. The sector has problems that require a solution and see research as a suitable tool. This does not mean that there is a direct line between research and problem solving. The road between basic knowledge and practical application can be long and winding. It is therefore a constant challenge to ensure funding for research that does not immediately give directly applicable results. Given the applied nature of transport research, there is no point in distinguishing between basic research and applied research. What we have done is to categorize the projects in VINNOVA's project base according to the field of applied research. Here we have distinguished between:

- Programme development and knowledge overviews

- Research for practical use, i.e. developing products and measures – for administration or for industry - and descriptions of the current situation (for example, a description of the accident situation) as the basis for measures
- Evaluating various concrete measures
- Research with a view to developing basic knowledge for the benefit of other areas of the research field and/or developing methodology for the benefit of other projects

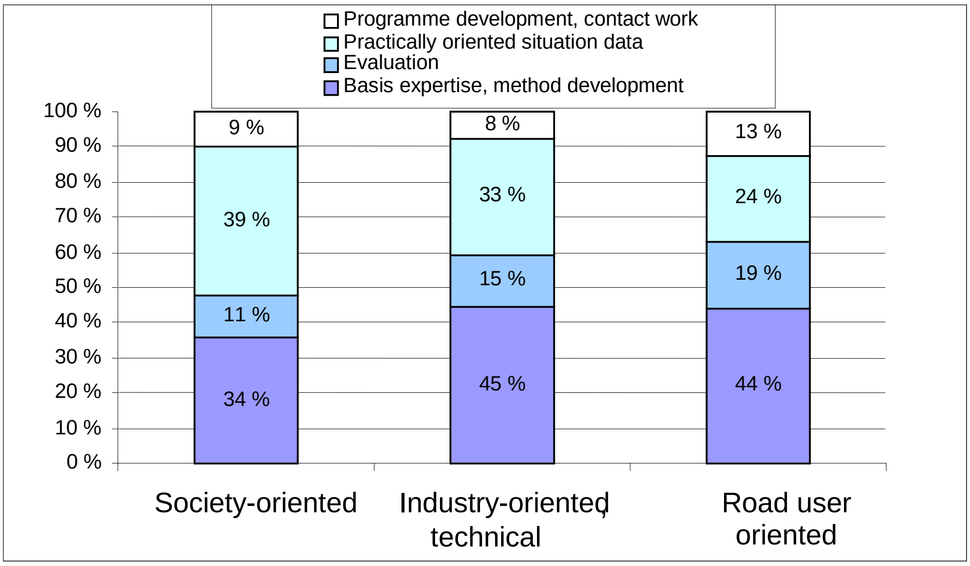
It is clear that there will be an overlap between these categories, if not by definition, given that many projects encompass several elements. The differences between the players are not so great along this dimension. PFF has the largest number of projects involving the development of methods and basis expertise, see figure 3.3.

Figure 3.3: Projects financed by TFD, TFB/KFB, VINNOVA or PFF in the period 1974-2004 according to main purpose of the research. Proportion of research projects (N=432)



The character of the research within the different thematic groups is shown in figure 3.4. We see that the proportion of projects where developing basic knowledge is the main goal is lowest for the more society-directed projects related to planning and road design, for example. In these categories, - projects with a practical purpose represent a larger proportion. The highest proportion of projects producing basic knowledge is to be found amongst the road user directed and the biomechanics projects (here put in the category of technically directed projects). With both these fields of research it appears that many projects are being carried out as PhD projects at the universities. The theme of the research, who is funding it and who is carrying out the research will thus affect the character of the research.

Figure 3.4: Projects financed by TFD, TFB/KFB, VINNOVA or PFF in the period 1974-2004 with different thematic focus by the main purpose of the research. Proportion of research projects (N=432)



3.8 Summary

Over a long period, Swedish society has invested relatively large sums of money into road safety research. Support for road safety research has been centred around a handful of central research institutes associated with universities or polytechnics or the institute sector. The re-organisation of the funding system in 2001 was intended to lead to closer collaboration between research and industry, and has this led to a significant change in the working conditions for the research institutes. The total financial support for road safety research has remained relatively stable, but in recent years a tendency can be seen towards a thematic change of the research effort, with fewer resources for society- and road user directed research, It is unclear to what extent this is compensated for through other forms of funding.

4 Four central institutions in Swedish road safety research

4.1 Self- evaluation and interviews– not traditional peer review

In this chapter, we will present the research institutes which have carried out and are carrying out most of the Swedish road safety research. We will give an overview of the important characteristics of the four major institutions, see table 4.1, and their budget constraints, see table 4.2. This is also an important background for the impacts we will be looking at later in the report. The account is based on the research institutions' self-evaluations and our interviews with staff. However this does not comprise a traditional *peer review* of the research at the institutions, given that, for example we have not paid much attention to the various institutions' different research areas, nor have we carried out a qualitative evaluation of all their scientific output.

4.2 Department of Psychology, Uppsala University

At the Department of Psychology at Uppsala, road safety research is a ”side project” in a large, renowned academic research institute, where the main tasks are basic research, teaching and training PhD students. The institution states that it currently spends 1.25 researcher man-years on research into road safety, and normally has one or two doctoral students working in this area. Researchers who previously worked on a project on a temporary basis no longer have the opportunity to work with road safety research, due to a lack of funding, and there is therefore a chance that the whole group may be wound up. The institution has a distinctively academic form of working with a relatively high number of publications centred round a small number of researchers, see references in Appendix 6.

At the beginning of the 1970s, the institution was dominated by perception research and projects on traffic in the dark and the detection of obstacles. Much work was also done on the acquisition of information through eye and head movements. Equipment for researching this was constructed and used in a number of projects. Important results from the Uppsala group are:

- The importance of keeping wild animals (game) from the roads, instead of changing behaviour: ca 1980
- Strategies for police enforcement with the emphasis on visible police presence, ca 1986, see Appendix 6

- Recommendation to reduce the number of ”railway crossings” with only sound and light signals: 1980s.

These studies show the value of the continuous development of methodology and knowledge that provide a basis for solving different types of problems. More recent theses (Björklund 2005 and Victor 2005) indicate that this development is not over. In recent years the institute has worked on new technology, GPS, user interfaces etc., but has not managed to obtain funding within these fields. In recent year the institute has worked together with Högskolan Dalarna and Teknikdalen in Borlänge on evaluating different ISA-trials (Intelligent Speed Adaptation). A thesis from 2006 indicates an interesting continuation of this related to HMI (Human-Machine-Interface) aspects (Wallén Warner 2006).

Researchers find it difficult to evaluate the impact of research, given that they have little contact with the administration. They know that the research on police enforcement was applied some years later, see Appendix 6, but do not know what the transfer mechanism is. This sets Uppsala University apart from institutions such as VTI, the work of which is to a larger extent commissioned, and that work in relatively close contact with users. The Department of Psychology at Uppsala University states that its main output is PhDs.

Table 4.1: Overview of important characteristics of the four major research institutions in Swedish road safety research, based on interviews and the institutions' self evaluations

Aspect	VTI	LTH	Chalmers	Uppsala University
Main areas	Technical re roads and vehicles, testing equipment, IT, traffic economics, training, road user groups etc	”Soft road users” conflict theory, design of the traffic environment, speed, ISA	Bio medicine, thresholds, whiplash, child safety, pedestrian safety, etc	Perception psychology, acquisition of information, police enforcement, cognitive functions, social psychology, explanation of behaviour
No. of researchers/ man years	50	10 Some decrease last year	22 Steadily increasing	1.25 Decrease
PhD students	Increasingly common	1-2 annually	Around 2 annually	About 1 annually from 1999
Disciplines Fields	Road technology, more recently also, statistics, economics, sociology, behavioural science, etc	Traffic technology, sociology, psychology, economics	Civil engineering, vehicle dynamics, industrial background, behavioural science	Psychology
Education	Contributes in the form of lecturers and supervisors. Education for developing counties.	Basic education, ca 100 students, Masters degree courses, 6 PhD students, further education, international TS-course. Less developed countries.	Course at Masters degree level, further education courses for engineers Researcher school.	No education, one-off courses for driving instructors for example, Courses in traffic psychology at doctoral level.
Publications	Circa 10 articles annually.	6-8 articles annually	From 8 to 18 articles annually	1-2 articles annually, 18 after 2000
Dissemination	Transport forum Internet pages A series of reports Courses	Lectures for municipalities etc, demonstrations, interviews. Riksdagens Trafikutskott.	Popular lectures Interviews	Handbook on road safety, some articles in the press, interviews. No input into politics/government.
Commercial applications	No	No	Dummies, courses. Contributes to car industry.	No
Funding	Basis funding. Work commissioned, esp. by Vägverket.	Decreasing - VINNOVA, and its predecessors, increasing - Vägverk and EU.	Decreasing proportion from VINNOVA, and its predecessors, increasing international (incl EU).	Gen decreasing. Previously mostly VINNOVA, and its predecessors.
Collaboration	Many EU projects, LTH, other academic.	Academic, EU-projects, international fora.	Car manufacturers, Autoliv, Folksam, academic, hospitals. Many foreign , both commercial and academic.	Mainly academic and Swedish.
Budget trends	Cut backs	Decrease after 2000, but somewhat better now	Increasing	Decreasing
Problems	VINNOVA has not made infra structure questions a priority. Difficult to get funding for city research	Need for more funding for long term and interdisciplinary research.	Difficult to obtain funding for basic research. manufacturing does not give money but time and equipment. .	Lacks funding for long-term development of knowledge and researcher education.

Some of the institutions have a relatively low number of publications in proportion to the number of employees. Publication rate varies strongly between disciplines, which makes comparisons between different research institutions problematic (Weller 2001). Average number of articles published in academic journals between 1986 and 1996 for American engineers employed by the state or in the manufacturing industry was 0.05 (Tenopir and King 2004), which shows that the publication rate for engineers is generally not very high.

4.3 Department of applied road safety (TTS), Chalmers

The institution is responsible for educating engineers and carries out technical and biomechanical safety research for car manufacturers . Chalmers has concentrated its research on passive safety i.e. systems that can protect road users from injury in the event of an accident. Now the aim is to change the research content and to put greater emphasis on active safety – systems that can prevent accidents. Chalmers safety unit currently employs around 22 researcher man years, a figure that has increased in recent years.

Important work at Chalmers that have been undertaken in collaboration with the manufacturing industry is:

- “Side impact protection” which was an industrial PhD project with Autoliv (An insurance company), and which resulted in Volvo’s side airbag, see Håland (1994) and Appendix 5
- Neck injury /whiplash research (see Eriksen et al 2004)
- New dummies for research into protection in head on collisions
- Compatibility with the road environment – regulations and test methods
- Test methods to evaluate pedestrian safety. The car industry has opposed to legislation in this area but the methods may be of greater significance now that pedestrian safety has become a factor in EuroNCAP
- New methods for protecting the lower extremities
- Development of the rearward facing child’s car seat prototype in the 1960s and the commercial product in the 1970s. see Appendix 4.

4.4 Section for road safety, Department of technology and society, LTH

This institution is part of the engineering degree training for traffic planners and one section is responsible for the road safety element. The main focus is on safety for vulnerable road users. The turnover of staff in the group has been small, and today the group consists of around 10 researchers, after some decrease in recent years. The group has a high degree of contact with society, with extensive further education and many initiatives to politician s. The group participates in a number of EU projects but seemingly publishes little in international journals. The figure has increased in recent years because there has been a move towards doctoral theses that consist of a number of articles.

Important areas of work at the institution are linked to:

- Safety in towns, where the institute has taken part in the development of major demonstration projects, for example in Växjö and Gothenburg. Roundabout and detailed design of footpaths, see Appendix 3
- Conflict technology as basic knowledge/methodology for understanding the interaction between different road users in the traffic system
- Trials with ISA (Intelligent Speed Adaptation), where evaluations have given promising results, but where there are problems with funding and the work has come to a halt.

The researchers at LTH are convinced that the traffic conflicts technique and behavioural studies will in due course be linked to a product, namely image processing technology that will provide completely new opportunities to demonstrate risk. There is reason to believe that the product development within this area could be of commercial interest.

In the EU, ISA- research is regarded as an important Swedish research field, see section 8.4. Sweden previously was far ahead in the field, as Lund began its ISA-research as early as 1986. In 1996 the first ISA-test was carried out with a speed limiter with 20 cars in Eslöv. Later a larger test was carried out in Lund with 220 cars using ISA-equipment for 6-10 months (Várhelyi et al 2004). The system made it difficult to drive faster than the speed limit (50 km/h). The ISA-research has been significant for example by ensuring LTH's participation in all the major EU-projects on speed and ISA. LTH has also taken part in the debate on this in the lobby organisation ETSC (European Transport Safety Council) in Brussels.

The institution considers the dissemination of knowledge very important. Dissemination takes place through both regular education programmes (including further education and education for developing countries); see chapter 5, and through information activities for decision makers, both centrally and locally.

4.5 Swedish national road- and transport research institute (VTI)

VTI, Swedish national road- and transport research institute, is an independent research institute within the transport sector. VTI was established by Den Kongelige Automobilklubben in 1923 as a Roads Institute and in 1971 was extended to become a Road and Traffic institute. VTI has several official functions and through this has a relatively close collaboration with the SNRA. Considerable work is done on technical testing of safety equipment, track and simulators, but also research on road users such as road user training and children's safety in traffic.

VTI works with all types of traffic and its core expertise is found within safety, economics, environment, traffic and transport analyses, public transport, behaviour and the interaction between humans - vehicles- transport systems, as well as within road construction, operation and maintenance. VTI's services cover everything from qualified reviews and expert opinions to project management, research and development. The institute's technical equipment includes driving simulators for roads and tracks, a road laboratory, equipment for testing tyres and collision tracks.

VTI has 180 employees and is based in Linköping, Borlänge, Stockholm and Gothenburg. About 40 % of the work is targeted at road safety. This comprises around 50 researchers**.** In recent years, the institution has established a stronger link to the universities, with co-operative projects, visiting professors and participation in several of VINNOVA's and SNRA centres of expertise, including SAFER in Gothenburg.

VTI emphasises the fact that it can be difficult to isolate their contribution to the field. The knowledge they develop is significant for safety policy decisions and contributes to the daily road safety work, such as road design, speed limits, risk target etc. Areas where VTI's research has had a major impact are, according to their own assessment: Use of mobiles, Seatbelt reminders, Testing child car seats and developing Iso-FIX, detection of fatigue and counter-measures, Flexible lamp posts, and Design of circulation areas. Other VTI-fields are Road user training and Child safety/ school transport.

VTI is also active in disseminating knowledge through participation in teaching and the VTI-days /Transport forum which is the main event in the Nordic countries for people in the transport sector.

4.6 The funding profiles of the institutions

4.6.1 Trends

In order to illustrate what the funding from VINNOVA and its predecessors and PFF means in relation to other sources of funding, we have looked at how the funding profile for the four research institutions changes over time. The public funding of road safety research increased up until 2000, and was reduced somewhat when VINNOVA took over from KFB, see table 3.1. All four receive a smaller proportion from VINNOVA/PFF than they formerly received from TFB/KFB and from 1994 from PFF. SNRA's share has increased for several of the institutes and the EU has become increasingly important for VTI and LTH, see table 4.2. The figures are not directly comparable. They must therefore be interpreted with great care.

Table 4.2: Various funding bodies' proportion of funding for research at VTI, Chalmers TTS, LTH and Uppsala University. Average share in different periods

Chalmers	**1971-80**	**1981-90**	**1991-2000**	**2001-05**
VINNOVA/ PFF/ TFD /TFB/ KFB	90 %	%	50 %	24 %
Public basis				13 %
VV+ Industry	10 %	%	%	32 %
Other (EU)	%	%	%	30 %
LTH	**1971-80**	**1981-90**	**1991-2000**	**2001-05**
VINNOVA/ PFF/ TFD /TFB/ KFB	80 %	60 %	15 %	10 %
Public basis	15 %	15 %	15 %	15 %
Vv+ TSV	5 %	10 %	50 %	55 %
Industry	0 %	0 %	0 %	0 %
Other (EU)	0 %	15 %	20 %	20 %
Uppsala University	**1971-80**	**1981-90**	**1991-2000**	**2001-05**
VINNOVA/ PFF/ TFD /TFB/ KFB	71 %	95 %	83 %	62 %
Public basis				
VV+ TSV	20 %	2.5 %	9 %	33 %
Industry	6 %	0.3 %	3 %	4.5 %
Other (EU)	3 %	2.2 %	3 %	0.5 %
VTI	**1971-80**	**1981-90**	**1991-2000**	**2001-05**
VINNOVA/ PFF/ TFD /TFB/ KFB	10 %	%	%	20 %
Public basis	50 %	50 %	20 %	10 %
VV+ TSV	40 %	%	%	50 %
Industry	10 %	10 %	10 %	10 %
Other (EU)	%	%	%	5-10 %

There are also major variations between years. The Department of Psychology at Uppsala which states that it received an average of 62 % from VINNOVA/PFF in the 2000s (the funding for 2000-2004 was given by KFB), has no funding from these sources for 2005. Given that the public funding bodies have been the principal external source of funding for this institution, there is clearly a challenge with regard to ensuring the development of expertise in traffic psychology in the future.

4.6.2 The research institutions' views on the restructuring in 2001

The closing down of KFB occurred at the same time that the research institutions experienced that SNRA provided less funds to research on road users. Therefore, it did not appear that increased responsibility, see section 3.3, was being followed up with an increase of funds in the road administration. Furthermore, KFB had anticipated transition problems and had put aside funding for several major longer term projects, so that the most central research institutes had something to fund work after the reorganisation. However, all four institutes tell the same story of financial problems, in particular for funding PhD students and the long term production of knowledge.

Chalmers, which is the research institute with the strongest growth in recent years, nonetheless experiences that there is strong competition for research funding in Sweden. One of the aims of establishing a *Vehicle and Traffic Safety Centre at Chalmers* (SAFER) is to strengthen their position in the competition for research funding. Vetenskapsrådet does not fund this type for research: basic research in the area of road safety is financed either by VINNOVA or the EU. Even though co-operation with the car manufacturers is close, it is becoming increasingly difficult to get funding from them. Contributions from manufacturing are given almost exclusively ”in kind” i.e. in the form of time. This makes public support even more important.

VTI states that it has observed a marked diversion of funding to vehicle technology research. Important research that was formerly carried out at VTI in areas such as the elderly in traffic and road design would be difficult to carry out today, since SNRA does not cover the long-term development of knowledge, and all projects must be related to concrete measures. The researchers state that without funding for theoretical development, research will become ineffective, since empirical results must be constantly repeated. At the same time, VTI appears to deal with the more consultant-like work for SNRA to SNRA's satisfaction and they believe that the problems have been greater for institutions in the university and polytechnic sector.

Researchers at LTH and Uppsala university are also experiencing the new funding regime as problematic. Until the year 2000 there was room for all the research institutions: sufficient funding was available in the system and each institution had its own niche. KFB wanted to support university research and focused on long-term development of knowledge. They are also experiencing that SNRA appears to show little interest in psychological research and in long-term projects, which has made the recruitment of new PhD students impossible. A number of the researchers who have worked in the institutions are in fact unemployed or work part-time. Uppsala university is part of an RND centre in Borlänge, but has not received the promised financial support. The situation illustrates the major significance of the system for funding and that not all models necessarily produce the desired behavioural additionality.

Since the research at LTH is directed towards training of researchers, the institution experienced major problems, as for a while it was difficult to obtain funding for long-term projects and PhD students. This was taken up explicitly with SNRA and the research group appears more positive about the future, due to increased budgets in SNRA, and the chance for funding for PhD students. They are also hopeful with regard to planned expertise and virtual centres.

Part of the problem may be transition problems. Increased funding to the research fields which had received less financial support and increased competitive ability internationally, for example through Swedish participation in new centres, may release new funding. These conditions are all linked: resources are needed to develop a level of quality which will succeed internationally. Further, it appears that new resources for vulnerable research fields require co-ordinated responsibility for the whole area of road safety. Without this, the effort gone into building up expertise at Uppsala university and LTH may be lost, and these are important parts of the whole of the area of road safety.

4.7 Summary

Funding from VINNOVA and its predecessors and PFF has provided funds for university and institute research, for disciplinary and interdisciplinary research, and for research in different fields. Four strong research institutes with a long history have been built up, and in total comprises between 80 and 100 researchers in road safety. The four research institutes which have received the lion’s share of funding from VINNOVA and its predecessors and PFF focus on relatively different thematic areas. This means that the restructuring of the funding system after the year 2000 has affected the four institutes differently. However, there appears to be a common opinion that long-term and basic research is more difficult to carry out than it was before, and that the new funding model and division of responsibility between VINNOVA and SNRA has not worked entirely as intended.

PART II - Impacts of public research funding

5 Academic results

5.1 Basic research with an applied perspective

A fundamental premise for public funding achieving impact is that the first step is successful, namely developing competent, competitive research institutions. In Sweden, the primary emphasis – with the exception of VTI, has been on linking road safety research with the universities. The challenge here is to ensure that the funding systems /tools are designed in such a way that the relevant university institutions are motivated to work in the field of safety, whether it is teaching at different levels, PhD programmes or other research. Here we will look at how the research institutions have responded to the grants from VINNOVA and its predecessors and PFF, what we can call behavioural additionality.

Studies have shown (Eaton et al 1999) that a country's innovativeness and ability to utilise new technology is dependent on that country's focus on basic research, and in small countries with an open economy, the majority (over 90 %) of the product development is linked to imported knowledge. Developing basic research at universities (or similar institutions) is therefore an important tool in developing a country's *absorption ability*, the ability to "catch up". Hervik (2004) indicates that there is a clear trend for basic research becoming more important as a source for the development of companies that are linked more closely to the basic research institutions.

Research and the acquisition of new knowledge happens at the universities and research institutions which have the means and skills for carrying out their own research which is assessed through scientific publications, peer-reviews and evaluations. Knowledge becomes accessible to other researchers, to society in general and to users of new knowledge partly through the education of scientific personnel, the transfer of knowledge through periodicals and conferences. The research institutions build up a knowledge base based on their own and others research (at home and abroad) and which in both the long and the short term is a resource for society when it is used whether by business/manufacturing, public institutions and organisations, politicians or others.

When focusing upon behavioural additionality, we cannot use economic valuation methods but must use a more classical evaluation of research institutions, and also try to compare one institution with other similar institutions by measuring a number of different characteristics. Indicators can be the number of scientific publications, doctoral degrees, advice given, networks created and cooperation with other institutions, user benefits of research through the number of patents and innovations in product and process development and the ability to create and disseminate expertise and knowledge. (See examples of indicators in table V.3, Appendix 2.)

The classic tradition of evaluating a research institution usually starts with a self evaluation which is followed up with a panel where key personnel are invited to an open hearing in order to ensure the quality of the self evaluation, which is in turn supplemented by further interviews and evaluations by a panel of experts. In the main, we have followed this tradition.. The main problem is weighting the different indicators as well as deciding what characterises a well-qualified research institution. The question is what level of quality to require and who to compare with whom.

5.2 Complementary content has answered society's needs

Given that road safety needs to be understood from a systems perspective, see section 2.1, it is interesting to see which areas have been stimulated by VINNOVA and its predecessors and PFF. Figures 5.1 and 5.2 show that the four major road safety institutions in Sweden have relatively different profiles. This applies to both the disciplinary profile and research area, and to the different road safety measures.

Figure 5.1: Research funding from VINNOVA and its predecessors and PFF to the four major Swedish road safety research institutes in the period 1974-2004 by the research topic of the project. Number of projects (N=253)

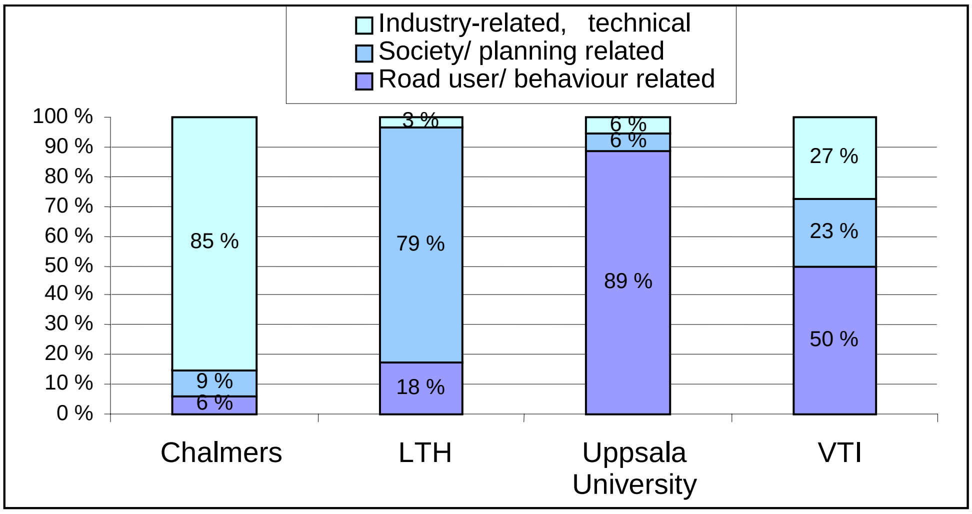
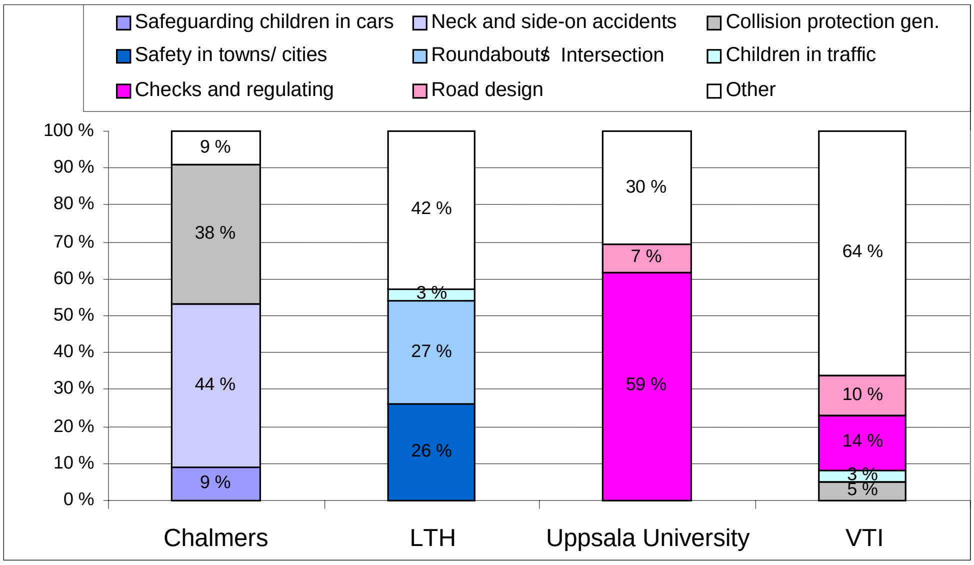


Figure 5.2: Research funds from VINNOVA and its predecessors and PFF to the four major Swedish road safety research institutions in the period 1974-2004 by the project's relation to various road safety measures within road safety work. Number of projects (N=244)



TTS at Chalmers has a clear focus on biomechanical research and research relevant for business, while the psychology department at Uppsala University focuses strongly on road user related research. At LTH and VTI the range of activities is wider and covers a number of other fields important for road safety, such as planning, road design, driver training and IT-technology. Together the Big Four also cover the development of knowledge for the measures that have had a particularly beneficial effect on road safety development, see chapter 7.

The fact that the institutions have different profiles has undoubtedly been a strength in Swedish road safety research. With easy access to funds, according to our interviewees, the feeling is not one of competition but rather of being able to provide mutual assitance when required. Given that road user-related research now receives far fewer resources than it did before, see section 3.7, it is important to bear in mind that this type of expertise is used across several fields and that students educated at Uppsala have gone on to work in other institutions such as VTI and Chalmers. All interviewees, whatever institution they come from, state the need to secure funding for research in the fields of behavioural science and planning research. For the new area of “intelligent” safety systems, for example, behavioural research will play a far more central role than has been the case previously for safety technology. The accumulated expertise within behavioural research may therefore prove to be a vital factor in the future, not least in relation to industry oriented research.

Several research communities expressed concern about the change of direction that has occurred, or rather the fact that the areas in KFB which were not moved to VINNOVA are now worse off. They say that this can make it more difficult to maintain the breadth that has characterised Swedish road safety research and which has brought results. Breadth and co-operation have been vital in breaking down boundaries and developing completely new perspectives,. There is also concern about how to ensure that such expertise exists when it is needed; see the quotation from a spokesperson from Chalmers in connection with the impact analysis.

> *”When industry is to implement various “intelligent” safety systems it is obvious that engineering knowledge needs to be supplemented with knowledge about human beings. A real example is Swedish car manufacturers who have completed systems for detecting tired/ sleepy drivers and some foreign manufacturers have, as far as I know, already started production of this system. The Swedes have hesitated toimplement the system since it is not known what is a suitable threshold for setting off the alarm. If the warning appears too early, there is a great risk that the driver experiences this as annoying since the risk awareness is often low. If the warning first appears when tiredness is obvious, it may be too late. In addition there is a risk that drivers may misuse the system in order to extent their working shift and to move ever closer to the level where they will fall asleep behind the wheel. Here we have one example of where the state funded the development of a research area that for a long time met with only limited interest from industry. In a relatively short time industry’s*

requirements have become almost acute. It is now obvious that the result of the state's long term input is a major resource for Swedish industry and hopefully this will now provide us with a competitive advantage".

In the interviews, the researchers also emphasised that the research becomes inefficient if there are no opportunities for carrying out more theoretical basic research, as empirical results then have constantly to be repeated. Hence focusing on short-term projects gives an impression of efficiency, because results are achieved rapidly, but this is less efficient in the long term.

5.3 Swedish safety research maintains a high academic level

There is a greater chance for research having impact in other areas if it is of a high quality The degree of success with regard to international publications is one way of measuring this, while another is participation in EU projects, see chapter 8. Knowledge must be transferred to others in order to be of use and Swedish road safety researchers have been good at publishing and disseminating their work internationally.

Impact factors (IF)[17] are used to give a rough impression of the academic prestige of journals, on the assumption that a journal with a higher IF has greater prestige and hence it is more difficult to have articles published. The large ISI database calculates the IF for 11 scientific publications within the field of "transportation" of which *Accident Analysis and Prevention* and *Journal of Safety Research* had a significant number of articles within the field of road safety. In addition the journal *Safety Science*, which has a broader focus on safety in relation to science and technology, contains numerous articles within the field of transport safety. Of these journals, Accident Analysis and Prevention (AAP) had an ISI Impact Factor of 1.717 in 2005, while the Journal of Safety Research (JSR) scored 1.263 and Safety Science had 0.606.

In the period 2000-2005 the ISI-database shows that 56 of a total of 635 (8.8 %) articles in *Accident Analysis and Prevention* originated in Sweden. For the *Journal of Safety Research* the Swedish figure for the

[17] The "ISI Impact factor" is a measures of how many times an average article in a given publication in the large ISIO research database is cited in journals in the database during the course of a given year. The annual impact factor is the relationship between citations and the number of published articles. The impact factor is calculated by dividing the number of citations in a given year by the number of citable units published in the two preceding years.

period is 6 articles of a total of 280, i.e. 2.1 %. *Safety Science* published 289 articles in this period, whereof 19 were Swedish, i.e. 6.6 %. In total, Swedish authors were responsible for 6.7 % of the total number of articles published in these three journals during the period in question (a total of 1204 articles), see table 5.2. By looking at the Swedish figures in relation to the figures for comparable countries, it can be seen that Sweden is extremely well represented in relation to the other countries. The exception is England, which, due to both language and its academic culture, is very highly represented within international publishing, as well as having a much larger population (50 million against 9 million in Sweden).

Table 5.2: Articles in the journals Accident Analysis and Prevention(AAP), Journal of Safety Research (JSR) and Safety Science(SS) 2000-2005. Number and percentage of articles by authors from countries that it is natural to compare with Sweden

Land	AAP	JSR	SS	Total %
Sweden	56 (8.81 %)	6 (2.14 %)	19 (6.57 %)	6.7
Denmark	14 (2.20 %)	3 (1.07 %)	6 (2.08 %)	1.9
Finland	16 (2.52 %)	8 (2.86 %)	11 (3.8 %)	2.9
Norway	18 (2.83 %)	1 (0.36 %)	11 (3.8 %)	2.5
The Netherlands	18 (2.83 %)	1 (0.36 %)	29 (10.0 %)	4.0
England (not UK)	48 (7.56 %)	12 (4.2 %)	43 (14.88 %)	8.6

Another important part of the academic contribution is teaching and PhD supervision. Currently Sweden produces around 6 doctorates in road safety annually. Given that funding is available for continuing their research, this forms a basis for maintaining the acquired expertise and transferring it to the next generation. The relatively high number of PhDs also indicates success in getting the university environments to focus on questions of road safety – which has been a goal for VINNOVA and its predecessors and PFF's funding over the years. Hence this leads to not only research projects necessarily come to an end but also to more long-term lasting fundamental expertise.

5.4 Swedish researchers actively participate internationally

5.4.1 Participate in half of the EU's safety projects

Within the field of transport in general (Surface Transport), until 24/1 2006 Sweden represented 5.5 % of participants and 6 % of the grants in the EU's 6th framework programme for research. The combined grants for Swedish research environments in this period were about 35 million EURO. This puts Sweden in 6th place behind Germany, Italy, France, Great Britain and The Netherlands, which is impressive taking population figures into account. The highest proportion of both grants and projects has gone to Chalmers.

We can also conclude that Swedish road safety researchers have been highly visible and active within the EU-research system. Swedish research institutions are participating or have participated in nearly half of road safety project in the EU's 6th Framework Programme (31 out of a total of 64 projects), see table V.1 in Appendix 2. Swedish participation has been strongest within the thematic areas of ”*infrastructure*” and ”*enforcement*”, while involvement in ”*behaviour*” is somewhat lower.

VTI, Chalmers and SNRA are all highly active within the system, which is confirmed by the interviewed representatives for DGTREN[18]. These three are participating/ have participated in 9, 8 and 7 projects respectively while other Swedish participants have each taken part only once or twice. It is rare for Sweden to undertake co-ordinating responsibility. Chalmers and SNRA have co-ordinated one programme each within the EU's 6th framework programme, while Lund co-ordinated two projects in the 5th framework programme. Participation in EU's framework programmes implies that the research is of a high quality given that participants in the EUs consortia go through a comprehensive evaluation process where all researchers and institutions are required to supply CVs.

Our interviewees from DGTREN and ETSC[19] were clearly of the opinion that Swedish researchers were amongst the best in Europe within the field of road safety, that Swedish research results were frequently referred to by researchers in the field and that Swedish researchers or institutions were often approached to obtain answers to questions concerning road safety. The representative from DG TREN emphasised that the Swedish institutions were regarded as among the best in Europe.

5.4.2 Major contribution to standardising work

Participation in ISO-committees is another international arena for exploiting research. Knowledge translated into international standards forms the basis for increased safety in several countries and also for increased application, for example, of Swedish products which meet these standard requirements. Sweden has participated actively in international standardising work in the

[18] DG TREN (*Directorate General for Energy and Transport*) is the EU-organ responsible for transport and energy policies and finances and organises much of the EU funded research within the area of road safety..

[19] ETSC (*European Transport Safety Council*) is an independent organisation that lobbies European decision makers (at a national and international level) to promote road safety. The organisation is financed by the member organisations, by grants from the EU commission and by sponsorship funding.

safety field. We would particularly like to emphasise the ISO work on better protection for children in cars, see Appendix 4. This work, which has been going on since the 1980s has been headed by Swedes and with Swedish researchers, including staff from VTI, amongst its members.

It is clear that in addition to publishing it is important to participate in other forms of international work in order to spread the research results in an effective way. The case study of child seats, see Appendix 4, shows that participation in international standardising work and groups that can make recommendations (such as OECD) are especially important for the practical transfer of knowledge. Swedish researchers, particularly from VTI and also from manufacturing, have taken up this challenge over the years.

5.4.3 Comprehensive dissemination to developing countries

Both VTI and the Trafik och Väg unit at LTH have made a significant contribution to disseminating Swedish road safety knowledge and expertise to other parts of the world, especially developing countries and the former Eastern Europe. Table V.2, in Appendix 2, gives a broad overview of the dissemination to non-Western countries.

Between 1985 and 2003 VTI mostly carried out internationally commissioned training and international consultancy through its daughter company *VTI Utveckling AB*; since 2003 this international work has been done within VTI. The courses in *Traffic Safety Management*, *Freight Management* and *Environment* and *Public Transport Management* together attracted some 1500 participants during the company’s lifetime. Recently SIDA has taken over responsibility for many of these courses.

LTH has also made a significant contribution to spreading road safety knowledge, partly in collaboration with VTI. They are responsible for the international SIDA-funded *Training Programme in Road Traffic Safety* which has been arranged annually since 2004, (a continuation of the courses for which VTI was previously responsible). The Lund group also runs short courses (1-2 weeks), primarily in their conflict study technique , behavioural studies and traffic planning. Here again SIDA has been the principal. They also lecture at a number of courses arranged by other institutions. The total number of participants is above 200, see the overview in table V.2 in Appendix 2.

5.5 Summary

Over the years a number of evaluations of Swedish road safety research have been carried out, including Peer Reviews of research institutions, evaluations of sources of funding and individual projects. We have looked at STU (1986)**,** Bjørnland et al (1989), Elvik, Salusjärvi and Syvänen (1993), Carlson et al (1999), Carstensen et al (2000) and Borcherding (2004). On the basis of these, interviews with the four major research institutions, and the impact analysis that was carried out, we can conclude as follows;

- Research funding from VINNOVA and its predecessors and PFF has created the basis for establishing several strong Swedish research intitutions in the area of road safety from the 1970s onwards.
- The four central institutions have become increasingly "academicised" in the period after 1980, in the sense that a larger proportion of researchers have doctorates.
- These environments have led to a substantial number of PhDs within the field of road safety. Sweden produces some 5-6 doctoral degrees in this area annually.
- VINNOVA and its predecessors has funded both university and institution based research, for both disciplinary and inter-disciplinary research.
- Road safety research directed at both society and industry has been funded.
- The quality of the research funded by VINNOVA and its predecessors and PFF is of a high international quality, is internationally well known and the institutions take part in international organisations.

The breadth and quality of road safety research at the four research institutions is such that Sweden stands out as an attractive co-operative partner in the international research market.

As stated, the Swedish authorities and politicians have been concerned to ensure that closing down of KFB and establishing VINNOVA from 2001 would not affect road safety research, see Wijkmark (2005). The researchers whom we have interviewed all express some concern for the long-term, development of basic knowledge and theories of road safety in the future and for funding for PhDs in the area. Support for such activities has provided incentives for the university environments to spend time on road safety and has also provided the necessary basis for the more applied sector research.

6 The impact of research on industry

6.1 Industry-directed research – some challenges

A classic problem when allocating research funding is whether funding should be given to the best institutions in order to make them even better or whether is should be given to promising new institutions. When allocating funding to industry-directed research, there are also problems related to the level of risk for the various investments and the question of industrial neutrality.[20]. For example, when should public funding be given to compensate for risk aversion or other incentive problems? Incentive problems are found amongst both applicants and funding authorities. In the struggle for scarce resources situations best described by game theory will arise, and “wrong” decisions may be taken due to insufficient information about the projects. Focus on measuring results can act as an incentive to chose safe projects in order to avoid ”blunders” which become visible if funding is given to too many risky projects (see Hervik, Bræin and Bergem 2005).

Allocating funds for basic research to the universities in order to be able to gain social benefits and economic profit in the long term can also add to the incentive problem. Goldfarb and Henrekson (2003), for example, have compared the incentive systems in American university system with the Swedish system. In Sweden the incentives have been greater for scientific publishing than for commercialising results and various types of bureaucratic measures have been introduced to counter this. Hence publications have been successful, commercialisation less so. In the USA the universities have reward systems for commercialisation and also enable researchers to work more flexibly with commercialising their results, and here commercialisation has been more successful. In Norway we have a similar problem to Sweden; Hervik et al (1997) show that the incentives for researchers to

[20] Where the aim is to develop measures to ensure R&D projects in industry, it is difficult to see how industrial neutrality can be maintained. In order to understand this, it may be helpful to distinguish between ex ante and ex post industrial neutrality. It is not possible ex post to maintain industrial neutrality. One has to choose the best projects and this will imply that some businesses are selected rather than others. Ex ante industrial neutrality means that at the outset all businesses have the same chance of winning the competition for subsidies. This means that ex ante no winner businesses are selected that have an advantage in the competition for subsidies. However, the question of industrial neutrality is less relevant when it comes to sector research, as in this study.

contribute to commercialisation are poor. They can become locked in publishing contests that lead to too little focus on commercialisation.

In the area of road safety which covers the interaction between road user, vehicle and roads, it is vehicle design that is most relevant for industrial and business development. In Sweden the car manufacturing industry is an important industry and accident research that can contribute to safer Swedish cars and Swedish equipment and service production in the same area, is an important tool in developing the industry. In Swedish transport and research policy this link is considered extremely important (Regjeringens strategi: Fordonsindustrien – en del av Innovative Sweden, Riksdagsproposition 2005/06:160 og SNRA 2005:114).

In Sweden research on safety in cars has been a success story with major economic significance, see the evaluation of whiplash research at Chalmers (Eriksen et al 2004). This success is the result of long-term work involving participants from academia, the manufacturing industry, the public authorities and the insurance industry. This purposeful cooperation has very probably been an important tool for avoiding the type of incentive problems described above.

Between 1994 - 2004 PFF supported some 30 projects with direct associations with industry, defined as projects where an industrial partner is the applicant or carries out the work. To this should be added the numerous projects where research institutions are the applicants, but where we know or can assume that the project subject of study is clearly relevant to Swedish industry. Projects within the theme of biomechanics, technology and IT accounted for 87 % of all projects funded by PFF in the period, see figure 3.2.

Self evaluations and interviews with representatives from the four largest research institutions within Swedish road safety research show several examples of research activity with commercial or potential commercial interest. In this project we have looked at three case studies of importance for industrial development of safety equipment, namely side impact protection (see Appendix 5), child car seats (see Appendix 4) and VTI’s simulator (see Appendix 7). In addition we also look at the whiplash study (Eriksen et al 2004). In this way we can concretise impact, estimate values and discuss different conditions for impact.

6.2 Calculation of national and international benefits

As stated in section 1.4 we can distinguish between industry-related benefits or impact at two levels:

- The economic cost-benefit expresses the ratio between costs and benefits for consumers, companies and society as a whole. The business economic profit at the national level is part of the economic calculation.
- The possible industry related benefits of increased exports are additional to the economic calculations and must therefore be calculated separately.

In Appendix 3 there is a general concretisation of how the total added value from the projects can be analysed, based on an economic cost-benefit model. When calculating economic benefits of road safety measures, it is common practice to assume that the benefit consists of reduced loss of life and health, reduced costs from loss of income and reduced costs of treatment in and outside hospital, material damage and administration. In many countries standardised prices have been prepared for this purpose. We use the Swedish recommendations given in SIKA (2005a), which are as follows:

Degree of injury	**Cost per incident 2001-prices (SEK)**
Death	17 511 000
Serious injury	3 124 000
Minor injury	175 000

Different accidents have different profiles with regard to the numbers killed, seriously injured or suffering minor injuries. These must be calculated on the basis of accident statistics or other sources. In addition data on the frequency of usage is required for many measures. For every measure with a known effect we can calculate the expected decrease in the risk of various traffic related injuries. When we know how many of these injuries can be expected during the course of one year, we can calculate the expected decrease in traffic injuries as a result of the actual measure. Multiplying this by the average costs for the type of injury concerned gives the annual benefit.

The benefit of a measure that makes cars safer can be expected to last for the whole lifetime of the vehicle. We assume that Swedish cars have an average functional life of 15 years[21]. The sum of discounted annual benefits

[21] This is somewhat shorter than SIKA's statistics show for the average lifetime, namely 17 years, but we assume that the driving distance decreases over the years so that this corresponds to 15 years with a constant driving distance.

using the recommended discount rate over this entire period is the present value The discount rate is 4 % p.a. at present (SIKA 2005a). In principle these calculations should cover the whole benefit to consumers and for industry. Some of the consumer benefit from better road safety will be transferred to the manufacturing industry in the form of a higher willingness to pay.

The benefits in the international market are somewhat different. Here, the benefit can in principle be measured by increased exports of road safety products and an increase in sales of Swedish cars that are due to the measure in question (i.e. where safety equipment has been installed). Identifying the sales benefit is not easy. We have chosen a simple solution by assuming the benefit is at least as great as the production and installation-costs for the safety equipment in question. This is based on the presumption that otherwise it would not be worth installing the equipment.

The economic calculations are somewhat speculative and sensitive to a number of doubtful assumptions. We have therefore chosen to use conservative estimates Sensitivity analysis for a couple of the calculations presented here can be found in Eriksen et al (2004).

6.3 Neck injury prevention and side impact air bags – successful co-operation

6.3.1 KFB funded an obviously risky project

The decision to focus on the long-term development of expertise in research on neck injuries was taken by KFB in 1985, when an application from Chalmers to carry out this type of research was granted. The focus on whiplash was regarded as risky. There was no guarantee of success in finding measures that could reduce whiplash injuries, which were an increasing problem.

Firstly there was almost no knowledge about this type of injury. Answers were needed to questions such as: How do neck injuries occur, especially whiplash? What are the causes and nature of the injuries? Without this type of knowledge it would not be possible to develop preventative measures. When funding was received from KFB, it was possible for a student to start a PhD work in traffic medicine.

The earlier research built partly on injury data from Folksam (An insurance company). Epidemiological analyses of this data showed that neck injuries appear to occur less often in car models where the seats were soft and often broke backwards in the event of a rear-end collision. A further discovery was that neck injuries were less frequent in models with high, solid headrests than in models where headrests were low or nor present. These two discoveries provided ideas on how neck injuries occurred and indirectly how they could be reduced.

The research at Chalmers increased in scope in the 1980s and 1990s. Experiments on animals were carried out which gave a better understanding of the mechanisms that lead to neck injuries. These are still not known in detail, but early in the 1990s the information was deemed to be good enough for it to be possible to develop measures to prevent or reduce the severity of such injuries. Close co-operation with the car manufacturing industry in developing measures to prevent neck injuries commenced. The research was now organised by a large consortium, where the most important partners were Chalmers, Folksam, Volvo Car Corporation, Saab and Autoliv.

In order to be able to develop a scientific foundation for a criterion for whiplash injuries, i.e. expressed as the maximum acceleration of the head and neck which a human being can tolerate before sustaining injury, a crash dummy was developed for rear impact accidents, BioRID (biofidelic rear impact dummy). With the help of crash simulations carried out using the dummy, a set of neck injury criteria has been developed. Chalmers states that it should be possible to use these to develop a rear impact crash test in the international car testing programme EuroNCAP (European New Car Assessment Programme).

Work on side impact protection is closely linked with research into neck injuries and anti-whiplash seats in particular. The knowledge base is much the same, but when testing side protection, a ”multi-directional crash-test dummy” must be used. THOR is an American crash dummy which, with the help of a ”multi-directional” neck construction inspired by BioRID, will be useful in testing side impact protection systems. A head on collision dummy with these properties is under development and will be used to test protection systems for ”corner to corner collisions”, (small overlap). See Appendix 5 for a more detailed description.

6.3.2 Collaboration between basic research and manufacturing has had an impact

The fundamental research within medicine and biomechanics at Chalmers has proved to be essential for Volvo Car Corporation and Saab being able to develop the measures to prevent whiplash which are now standard equipment in their cars. Without basic knowledge of the mechanism behind whiplash injuries, they simply would not have known how to prevent or reduce the severity of such injuries..

Chalmers regards collaboration with the car manufacturers and Autoliv as very productive. With PFF, which came in 1994, a form of funding was established which facilitated such collaboration. Hence it became possible to exploit the knowledge for testing and developing products for increased safety. An important form of collaboration has been the so-called ”industrial PhDs”, where employees in manufacturing industry study for PhDs at Chalmers, funded by their employer. These industrial doctorates have contributed to product development at both Volvo Car Corporation and Autoliv.

TFB/KFB, VINNOVA and PFF have all supported research in the development of various forms of collision protection. Chalmers regards PFF as a productive and non-bureaucratic model for cooperation between industry and research, where the closeness between participants in the consortium has positive impact.

6.4 Child car seats – a genuine Swedish invention

6.4.1 Interdisciplinary research with links to the authorities, manufacturing and the insurance companies

The rearward facing child car seat was invented at the inter-disciplinary research environment in Trafiksäkerhetsrådet early in the 1960s, where it was also feasible to try out various ways to protect children (Aldman 1962, 1963, 1964, 1966, Isaksson- Hellman et al 1997, Carlsson et al 1989), see Appendix 4. Technical, medical and behavioural research were all important in order to understand that children are not small adults, and that different solutions are needed to distribute the collision forces better than a standard safety belt, such as the rearward facing child seat. If the technology is not used correctly, it will have little effect , hence knowledge of user behaviour is also required. See Appendix 4 for further explanation.

The research was funded from the council’s own funds and also by Volvo (including the cost of collision tests) and Forsikringsselskapet Folksam (Chalmers self evaluation 2006). Volvo created a prototype seat as early as 1966. According to Carlsson et al (1989), the seat was available on the Swedish market towards the end of the 1960s. Hylte and Klippan produced child seats from 1968 and in 1972 Volvo entered the market with their own rearward facing child car seat. Volvo and Chalmers had a discussion about child car seats in 1972. The close contact between different players in product development and also with the board of the Trafiksäkerhetsrådet contributed to a rapid dissemination of knowledge and the implementation of the innovation.

The basic research in this field was carried out before 1971. The research council’s responsibilities was taken over by TFD from 1971 and after that by TFB, KFB and PFF, see chapter 3. Since 1971, a total of SEK 18.8 million (2000-kroner) has been spent on 19 projects concerning children and traffic. The majority of projects deal with children in traffic, while SEK 6.2 million has been allocated to children in cars. The figure includes participation in international standardising work.

6.4.2 Behaviour-related research is necessary to ensure use

In 1971, VTI took over parts of the Trafiksäkerhetsrådets research work and laboratory work and today VTI's crash test laboratory is responsible for testing child protection equipment. VTI's work in the field of child protection covers research (for example related to people's use of equipment) studies of samples of accidents, tests and participation in international standards development.

The development of the rearwards facing seat and knowledge of its advantages has not on its own been sufficient to ensure the use – and in particular the correct use – of this measure. Over the years VTI has carried out a number of related studies that have been important in exploiting the effect of rearward-facing child car seats. Four such research themes where much work has been done in Sweden and abroad are:

1. Effects under different conditions – for example the child's' age versus length, any unexpected injuries, problems with airbags etc.
2. Non-use of the products and effects of measures to increase usage. This has included looking at the effects of legislation, regulations and campaigns..
3. Incorrect use of the product, reasons for this and impact of measures to correct this, such as campaigns, information and simplification of the system.
4. Product development, different types of seats and fastening systems, including standardising seats and fastenings.

Swedish research institutions, especially VTI (see the overview of publications in Appendix 4) have carried out extensive studies within all these fields. The close connection between testing activity, use of laboratories and other research is seen as fundamental for the further development of the equipment and practical exploitation of the research results (VTI's self evaluation 2006). At the same time VTI points out that compared to other research institutions, VTI, as a legal authority, is less able to work closely with manufacturing or to develop commercial products itself.

VTI's research on children in cars has been funded from their own funds (state- based funding), funds from TFD, funds from the administration bodies (Vägverk, Trafiksäkerhetsverk (TSV), Skyltfond) and by fees from manufacturers who want to have equipment tested. At Chalmers, work is now underway on child restraints with support from PFF and EU and in co-operation with Volvo Car Corporation and Saab. Chalmers has close contact with the manufacturing industry through funding, collaboration on projects, associate professors and doctorates funded by manufacturing.

6.5 VTI's simulator – necessary for product development

6.5.1 Important for situations that cannot be studied in normal traffic

The driving simulator with a moveable platform was first used at VTI in the spring of 1983. Planning the driving simulator had been going on since the 1960s and simpler simulators had been in use since 1978. The driving simulator in Linköping is highly advanced and allows sidewise movement (rails) in addition to movement with the help of hydraulic cylinders.

The car manufacturers in Sweden (GM/SAAB and Volvo Car Corporation) are important users and have benefited greatly from VTI's driving simulator in Linköping, even though they have their own simulators and also use other simulators (for example in Detroit and Gothenburg). The industry's spokespersons state that the individual companies could not have built such an advanced driving simulator in Sweden with their own funding. VTI's researchers also know how the simulator should be used in order to achieve valid results. They recommend methods and testing programmes to study problems that the companies want to investigate and also evaluate recorded data from tests in the simulator. VTI is also in contact with a group of people who do not suffer from simulator sickness and who are suitable for trials in the simulator.

The simulator's location in Sweden means that collaboration and the development of expertise in Swedish industry are greater than if similar tests had been carried out in the USA or Germany. VTI's simulator also contributes towards close collaboration and contacts between Swedish research institutions such as Chalmers, Kungliga Tekniska Högskolan (KTH) Linköpings tekniska högskola (LiTH) and VTI. A number of the simulator projects have been carried out in collaboration with other research institutions. It is quite clear that access to the simulator has in some cases been totally decisive for the establishment of co-operative projects. Internationally the simulator has also been a source of collaboration , project participation and publishing.

A large amount of research is done in cooperation with competing car manufacturers such as Volvo Car Corporation, Saab and/or Scania. This applies to the more basic development of knowledge and methodology. One example of a common research area is testing the validity of simulator tests.

Concept testing is done both internally and in collaboration with trusted partners.

Tests that involve a high risk for drivers can only be done in simulators and not in real traffic. Areas where there are clear advantages in using the simulator include research into the design of complicated road systems and tunnels, the risk in using alcohol/ medicines, including tiredness and sleep apnoea. Simulator studies in collaboration with VTI's specialists in road safety, for example, have resulted in research at a high international level with regard to effects of tiredness on driver behaviour. The possibility of detecting tiredness and to use this in warning systems with a view to preventing drivers from falling asleep or driving when tired have also been studied. (Ingre et al 2006a; 2006b).

Appendix 7 gives a comprehensive overview of what the simulator at VTI is used for and the publications that have come out of this research. Since the results of the car industry's simulator research are often classified as secret or confidential, it is not possible to give a full overview of the results, or to carry out a economic analysis of the significance of this research

6.5.2 Public research funding has acted as a catalyst

The most significant sources of funding for the research projects that have been carried out using VTI simulator have been SNRA, KFB, VINNOVA, PFF and the EU. We have collected information about sources of funding for 39 projects of which several have shared funding (see Appendix 7). The Research Councils have supported 13 projects, the EU 19, industrial partners 5 and public authorities (mostly SNRA and previously The Swedish Road Safety Office) 23 projects. The share of manufacturing is higher than this estimate indicates. Many of the projects that are funded by industry are business secrets and we cannot therefore give precise information about these. According to information from VTI, the simulator has been used for work for the car manufacturing industry in the following countries (number of clients in brackets): Germany (1), USA (1), France (2), Japan (3), Sweden (4).

GM (SAAB) is very satisfied with the projects and the research financed by VINNOVA and its predecessors and PFF. The application process and reporting are rational, short and non-bureaucratic. Projects with Swedish funding have been characterised by flexibility and efficient collaboration. Projects within the vehicle research programme (PFF) are guided by the manufacturing industry's needs and wishes. Projects with Swedish funding are regarded as administratively simpler and more useful than EU-funded projects.

Since VTI's simulator is both advanced and expensive to use, the car industry's self-funded projects are often carried out using equipment that is less expensive for the users. The more expensive VTI-simulator is then used to verify results under the most realistic conditions possible. In the final phase of a project, VTI's simulator can also be used to chose between actual solutions that have come from tests in simpler simulators. Users – both public and private – all agree that public funding of the simulator development from KFB, VINNOVA and PFF has been and remains a necessary catalyst for basic research and new projects. Further governmental funding will be required when the current programme comes to an end, if Swedish industry is to maintain its high expertise and position with both Ford and GM respectively

6.6 Economic impact analyses

6.6.1 Major benefits from whiplash protection

Annually 2 000 people in Sweden become disabled as a result of neck injuries (Krafft et al 2003). We have assumed that this is synonymous with neck injuries with a duration of more than six months, i.e. serious neck injuries. In addition, there are 20 000 minor neck injuries annually. Neck injuries in total comprise two thirds of all traffic injuries that have permanent consequences.

Different measures against neck injuries (whiplash) are described in Eriksen et al (2004) and are taken to apply to all Volvo Car Corporation and Saab cars. According to an evaluation carried out by Folksam (Krafft et al op. cit.), Volvo's and Saab's whiplash protection reduces the frequency of neck injuries which result in symptoms for a period of up to six months after the accident by 6 %. The frequency of whiplash with symptoms lasting more than six months after the accident is reduced by 39 %. Taking into account results from other studies (see the overview in Eriksen et al 2004) we find a reduction of 50 % for serious whiplash injuries and 20 % for minor whiplash injuries.

Car statistics from SIKA show that sales of new cars in 1997, when whiplash-protection was introduced comprised 258 000 cars, while in 2002 the figure was 290 000 cars. Of these 79 000 were Volvos or Saabs. It can be estimated that about 250 000 Volvo and Saab have whiplash protection,. In Sweden the total number of registered cars is around 4 000 000. If we assume that the 250 000 cars with whiplash protection have the same accident frequency as the rest of the vehicle fleet, 125 serious whiplash injuries can be expected from these cars. Based on the calculated percentage injury reduction, it should be possible to avoid *63* of the serious neck injuries and *250* of the minor injuries annually.

Based on SIKA's (2005a) rates for economic costs of road accidents (2001-priser), we obtain an annual benefit of:

Fewer serious injuries: *2 mill SEK x 63 = 125 mill SEK*

Fewer minor injuries: *0.175 mill SEK x 250 = 44 mill SEK*

Together these comprise SEK169 million annually and SEK 675 annually per car. Discounted over the whole lifetime of the car, 15 years at 4 % p.a, the benefit has a present value of SEK 1 900 million. The calculation does not take into account that more cars will be equipped with whiplash protection in the future

6.6.2 The effect of side impact protection for the head

A study carried out by the American Insurance Institute for Highway Safety (IIHS) concludes that different types of side impact protection for the head can reduce the risk of death by 45 % (Braver and Kyrychenko 2003). In line with Krafft et al (2003) this study uses data from actual accidents.

Based on the accident statistics from 2002 we have identified the accidents where side impact protection can be assumed to work, i.e. pure side impact collisions at intersections, turning off the road and U turns as well a small fraction (10 %) of single vehicle accidents and other accidents where cars crash at an angle. On the basis of this and taking into account the level of reporting, we arrive at 69 deaths, 942 serious accidents and 7 815 minor accidents which result from side - or right-angle impacts.

Today more than 75 % of new cars that are sold in Sweden are equipped with side impact protection for the head. Assuming that the first cars with side impact protection came on the market 1998, the proportion of the number of kilometres driven by cars with side impact protection in 2005 can be estimated conservatively at around 35 %. If cars equipped with side impact protection are involved in the same number of accidents per kilometre driven as cars without such protection, we can expect that they will be involved in accidents with 24 deaths, 330 serious injuries and 2735 minor injuries annually.

Based on Braver & Kyrychenko (2003) we calculate that side impact protection for the head reduces the risk of death by 45 %. The study has no information on the effectiveness of side impact protection to reduce serious accidents If we assume that some deaths would be serious head injuries instead, we can set the accident reduction effect for serious accidents to at half the value for risk of death, i.e. 23 %. Due to the uncertainty, we have not assumed any reduction in the number of minor injuries. This means that side impact protection can broadly be calculated to prevent 10 deaths and 75 serious injuries annually.

Using the economic costs of road accidents (SIKA 2005a) the annual benefit will be (2001 prices):

Fewer deaths: 17.5 mill SEK x 10 = 175 mill SEK

Fewer serious injuries: 3.1 mill SEK x 75 = 232.5 mill SEK

The benefit amounts to a total of SEK 407.5 million annually or an average of SEK 313 per car annually. Discounted over the whole lifetime of a car, this amounts to SEK 4665 million for these 1,300.000 cars. The fact that more cars will have this type of protection in the future is not taken into account here.

6.6.3 Child car seats

The calculation of the benefit of child restraints in cars is based on the available accident data, exposure figures from travel survey data (Thulin and Kronberg 1998), and estimates of expected growth in traffic, see Appendix 4 for a more detailed description. This gives the following rounded-off figures for expected injury impact for children aged between 0-3 years:

- Expected annual number of slightly injured children 190
- Expected annual number seriously injured children 15
- Expected annual number killed children 5

These injury figures reflect the current level of child restraints in cars in Sweden. It is assumed that child restraints in cars are as shown in Appendix 4, with 95 % of children under 1 year, 80 % of children between 1-2 years and 20 % of children between 2-3 years sitting in child car seats.

In order to calculate the benefit of this level of protection for children in cars we have used data from the Norwegian Traffic Safety Handbook (Elvik et al 1997, Amundsen and Elvik 2007). The handbook's meta-analysis of results from various studies shows that the risk of injury is reduced by 80 % (taking all levels of injury together) for children seated in rearward facing child car seats. The effect of a seat cushion with a seat belt is set at 60 % reduction in injuries and the effect of a car seat belt alone is set at 25 % reduction in injuries. Seat belts alone have less of an injury-reducing effect for small children than for bigger children and adults.

On the basis of today’s annual injury figures, we find that without child restraints in cars, these figures would have been:

- 21 killed, i.e. 16 more than today’s expected number.
- 52 serious injuries, i.e. 38 more than today’s expected number.
- 675 minor injuries i.e. 504 more than today’s expected number.

Assuming the safety equipment is used for three years for, the benefit of fewer deaths will be:

17.5 mill SEK x 16 x 2.775 = 777 mill SEK.

Here SEK 17.5 million(17 511 000 in 2001 prices) is the cost of one death; 16 is the number of deaths which are prevented and 2.775 is the present value factor for 3 years with 4 % discount rate. A similar calculation finds that the benefit of fewer serious injuries is SEK 329 million, and for fewer minor injuries SEK 244 million.

The total benefit is calculated at SEK 1 350 million. Annual investment in safety equipment is calculated at SEK 210 million. The calculation indicates that the benefit to society of child restraints in cars clearly exceeds the costs. One question is whether research costs and the public costs of information etc should also be included. It is obvious that the benefits far exceed the public funds that are set aside for this research.

We have limited the calculation to children under the age of 4, where the use of rearwards facing seats is specifically recommended. One possible additional calculation - provided that the data are available- would be to look at the under-7 age group who are also required to be protected in cars. It may also possible to look at the benefit/costs of everyone using recommended child seats. This type of approach would be useful in evaluating the benefit of extra input to increase the usage and also possibly for the commercial potential.

6.7 The benefits of exports for industry

The calculations which are given above show the value to the Swedish consumer of these measures. The profit from the sales of these cars and safety - products will be included in the domestic willingness to pay. The net increase in exports due to the improvement in quality is, however, a benefit for Swedish industry and hence also for Sweden.

Isolating the impact of this would be somewhat speculative. However, if we do attempt these calculations, we can assume that the production costs of whiplash protection is SEK 200 in per car. The production costs of side impact cushions in the form of ”crash curtains” are estimated to be

SEK 1000 per car. In total, these safety components cost SEK 1200 according to our estimates. If we assume that the safety equipment increases the car's market value by at least the production costs, this amounts to about SEK 1200 per car. If we assume that some 350 000 Saabs and Volvos are exported annually from Sweden, the annual benefit of this would be SEK 420 million.

The profit from Autolivs's export of side impact protection in cars is growing rapidly and was assumed to be SEK 10 billion in 2002. A large part of this is produced abroad for the foreign market. In 2003, Autoliv sold side impact protection for 400 000 Swedish cars. If 350 000 of these were exported, the value of this safety equipment would be SEK 420 million annually if the value is SEK 1 200 per car. This is the same as the profit due to the export increase for Saab and Volvo Car Corporation, as calculated above. Autoliv's share of the production of side impact cushions on the world market is large but not known. It is even more uncertain how much of this surplus can be ascribed to these products and which later end up in Sweden, but the figures can be high.

Child car seats that are not exported from Sweden so no evaluation of the international profits has been carried out, However the innovation is widely used abroad, partly as a result of Swedish researchers' participation in standardising work and through international co-operation, see chapter 8 and Appendix 4.

The uncertainty in the calculations is large but they give a clear impression that these product groups are highly profitable in a socio economic sense. Even though we do not know all the underlying research and development costs, there is little to indicate that they approach the benefit value calculated in SEK. Nor do the calculations tell us anything about the benefits dependence on the research and development effort.. The calculations that are presented here only apply to the existing car stock. It is clear that the potential for future profits may be substantial.

We have not succeeded in providing a complete overview of the cost of research and development that lies behind these products, Much of the problems lies in the difficulties in allocating costs to different products. Contributions from governmental funding sources such as VINNOVA and PFF can be identified, but only form part of the whole. The total funding from PFF to the Department of applied road safety (TTS) at Chalmers from 1994 to 2003 comprised SEK 23.8 million. Here manufacturing contributed a matching amount so that the total extent of this effort was SEK 47.6 million. Chalmers internally-funded share of the whiplash research is not known. For VINNOVA and its predecessors the contribution was SEK 33.1 million from 1985 to 2003. Here it should be noted that TTS has participated in other projects.

For Saab and Volvo Car Corporation the development costs for whiplash protection are estimated at between SEK1.5 and 2 million annually from 1994 to 2003. The estimate is based on interviews with representatives from the car manufacturers. This is in addition to the pure research projects, see PFF above, where Autoliv also participates. Autoliv is a research-based group of companies that annually spends large sums of money on research and development. The proportion spent on whiplash measures is not known. Whiplash research has also been carried out at other research institutions in Sweden. The cost of this is not known.

6.7.1 USA – an example of calculating the value for other countries

It is not just in Sweden that these safety products have been of major economic significance. As an example of the impact for another Western country with high accident costs, we have investigated the consequences for the American consumer if Saab- and Volvo-cars that are sold on the American market with similar whiplash protection, pre-installed. To do this we have to make some simplifying assumptions. We assume that the injury-reducing impact is the same as for Saab and Volvo in Sweden.

The biggest difference between the USA and Scandinavia with regard to cars is car usage. With a population of 264 million there are some 133 million private cars, i.e. about the same density as in Sweden. However, the annual mileage per car is believed to be far higher in the USA, which should be reflected in the number of accidents..

The valuation of the benefit of avoided accidents is based on an article by Zaloshnja et al (2004). To make their figures comparable with our earlier calculations, we have converted the figures to SEK and merged the two lowest American injury severities. We then obtain a cost of approx, SEK 3.5 million for a serious neck injury and SEK 200 000 for a minor neck injury. This is somewhat higher than we had used for Sweden (respectively SEK 2.0 million and SEK 175 000).

We do not have definite figures for the number of cars with pre-installed whiplash protection on the American market, but here we estimate the total to be around 1 million. The total number of whiplash-injures in the USA is stated by various sources to be 1 million annually. Of these, about 140 000 are assumed to be serious. We assume that as for Sweden the injury-reducing effect of whiplash projection in cars is 50 per cent for serious injuries and 20 percent for minor injuries. For our estimate of 1 000 000 cars the expected number of serious whiplash injuries would be 1 037. With whiplash protection the expected number of injures would reduced by 519. Minor injuries would be reduced by 1 274.

This implies an annual cost saving of SEK 2.1 billion. Discounted over an assumed lifetime of 10 years for American cars, the total benefit for these cars would be SEK 18.7 billion. Per car the annual benefit is SEK 2 070 and discounted over 10 years, this becomes SEK 18 700.

We can see that this is a considerably higher average benefit than for Sweden. This is due to a combination of an annual accident frequency that is twice as high and somewhat higher accident costs. Whether this higher accident frequency is realistic will not be discussed here but it is clear that cars that are driven more are more exposed to accidents. It is not known what the situation is like in other countries, but Sweden is assumed to be more like the rest of Europe than the USA is.

6.7.2 The benefit of a head start in research

Autoliv is a world leader in side airbags and other types of protection that are specifically designed to protect the head.. Other manufactures have also come onto the market, but there is still reason to believe that Autoliv is considerably ahead.

In sections 6.6.1 and 6.6.2 we have calculated the value for Sweden of two product groups, whiplash protection and side impact protection for the head, being on the market. However the calculations alone do not indicate the importance of the Swedish research effort . In order to be able to say anything about this, we must first be able to prove that it is unlikely that this technological development would have taken place without funding from the Swedish government through VINNOVA and its predecessors. With regard to whiplash research, it is relatively obvious that this would not have come into being without funding from these players. PFF has also been of major significance. This became very clear in the interviews with researchers and manufacturers.

The development of side impact protection for the head has to a large extent been the result of the expertise at and around Chalmers. This group has to a very great extent been dependent on funding from KFB, VINNOVA and PFF. The development of side impact protection has been completely dependent this support. How far ahead this research is can only be assessed subjectively and it is highly uncertain. In Eriksen et al (2004) such assessments have been carried out, but we regard them as highly uncertain. It is also uncertain whether this research advantage could be assessed in the same way today.

6.8 Summary – total benefit

If we add up the total benefits for Swedish consumers and the benefits for manufacturing, we arrive at a total annual benefit of at least SEK 1 500 million for these safety products. However it is doubtful whether this is meaningful as the method used for the calculations is very different.

The case studies indicate that the public funding that has gone to these projects has been useful for manufacturing. Funds have been given for the building of infrastructure such as simulators, developing crash dummies, doctoral studies and to manufacturing which has bought services from these institutions. Funding to manufacturing has been sufficient to contribute towards results, but it is not possible many years later to identify the input-additionality of the funding. There are examples of public funding releasing funding and resources in manufacturing, but also that projects have been carried out by manufacturing even when the funding was less than expected.

With public funding, over time a comprehensive research collaboration has developed that is partly open to entry, where a number of competing enterprises (from both manufacturing and research) can participate, where expertise is brought in from a number of disciplines, and where there is international participation. There are therefore reasons for maintaining that the funding has affected the scope of co-operation positively, i.e. has had high behavioural additionality. In the interviewees' opinion, Swedish safety research has had major significance and may well have been decisive for the fact that cars and equipment are still being manufactured in Sweden. Significant economic impact of safety measures in cars has also been documented. This type of end impact of a long-term focus on safety research demonstrates substantial benefits and hence high output-additionality.

Together with other parties, VINNOVA has already taken a further step towards new goals for research and development of safety in cars. The ongoing development of the infrastructure for research at Lindholmen in Gothenburg around the vehicle manufacturing cluster[22] is an important measure in further developing comparative advantages for Swedish safety-related vehicle/ suppliersmanufacturers.

Such a venture can be a decisive measure for ensuring the future success of the industry- directed part of Swedish road safety research. Such focus will put heavy demands on all players, see the discussion in section 6.1.

[22] This includes for example Test Site Sweden and the new safety research centre SAFER. Both Chalmers and VTI have joined with VINNOVA and a number of industrial partners.

In connection with future work, we emphasise that it is important to stimulate user-guided programmes where manufacturing or other users define the problems and which provide incentives for more use of the knowledge capital in basic research institutions. This includes ensuring that university environments are also guaranteed continued resources for basic research and knowledge development that is relevant to, and of interest for the road safety research of the future.

7 Impacts on accident development

7.1 Analysis based on factors where we know the effect

The aim of road safety research is to contribute to increased safety. In this chapter we will attempt to estimate the size of the contribution of different factors, especially measures based on Swedish research, to road safety progress in Sweden after about 1970. A number of problems are linked to explaining the long-term trend of road safety (see Elvik 2006). Some main points are:

1. Traffic safety and changes in this over time are influenced by a very large number of factors. Good data is available for only a small number of these factors.
2. Some of the factors that affect road safety are strongly correlated. This makes it difficult, even with advanced statistical analyses, to separate out the contributions of the various factors.
3. Using years as units, there are about 35 data points after 1970. This means that the number of factors for which effects can be calculated using multivariate analyses is very limited.

Since a multivariate analysis of factors that can affect road safety is not feasible, we have carried out a more informal analysis, strongly inspired by Evans (1991, chapter 13). The main questions can be formulatedas:

- What are the most import factors that have influenced road safety development in Sweden after 1970?
- What contribution has been made to the development of road safety by Swedish road safety research and measures developed with the help of Swedish road safety research?

The study is limited to factors for which information is easily accessible and which have been broadly tested in practice. This does not mean that factors other than those considered here are not significant, only that on the basis of the available information, it has not been possible to estimate their effects in a meaningful way. It is important to remember this when interpreting the results. The factors that are included in the analysis are shown in table 7.1.

Table 7.1: Contribution of different factors to road safety development in Sweden – estimates for the importance of research. Measures related to the projects case studies are shown on a blue background.

Area of measures	Factors that have influenced road safety development	Significance of research for developing the measures
Exposure	Total volume of travel	No significance
	Journey distribution by mode of transport	No significance
Road network's safety standard	Construction of motorways	Some significance
	Construction of roads with median barriers	Major significance
	Speed reducing measures in towns and cities	Major significance
Cars safety standard	Development and use of seat belts	Some significance
	Development and use of protective equipment for children in cars	Major significance
	Development of better protection against whiplash and side impact collisions	Major significance
	Other improvements to vehicle crashworthiness	Some significance
Road user-targeted measures	More effective police enforcement	Some significance

Table 7.1 only shows the significance of research for the development of the measures. The impact on accidents will be considered in section 7.2.
Table 7.1 shows an attempt to classify the importance of Swedish road safety research for the various factors. For example, it is assumed that road safety research has not affected the trend in the volume of travel and the share of various modes of transport. On the other hand, it is assumed that the research has had some influence in developing methods of police enforcement. Evaluation and analysis of practical measures lie within our definition of research. The classification is discretionary and is open to discussion. It has been made on the basis of knowledge about the amount of research that is to be found in the various areas, the country of origin of the research and the impact in Sweden.

Areas where Swedish road safety research, judged on the basis of this projects various analyses and the whiplash study (Eriksen et al 2004), are judged to have been of major significance for developing and implementing road safety measures are:

- Constructing roads with barriers to separate traffic in opposite directions (Carlsson og Brüde 2005). Sweden was a front-runner with this measure. The measure has been developed as a direct result of establishing Vision Zero as the basis for Swedish road safety policies.
- Developing and introducing speed reducing measures in towns and cities, where Swedish research was well ahead in studying the effect of speed humps and other speed reducing measures such as mini roundabouts. The principles for safer design of streets and roads in towns and cities –Calmed streets– have been developed as a result of setting Vision Zero as the basis for Swedish road safety policies (Brandberg et al 1998, Svenska kommunförbundet 2000), see Appendix 3.
- Developing and encouraging the use of protective equipment for children in cars, in particular rearward-facing child car seats. Swedish research was a forerunner in this area and designed the principles for today's solutions as early as the first half of the 1960s. Important follow-up research and development took place after 1970, however, see Appendix 4
- Development of better protection against whiplash in cars. This measure was previously evaluated for VINNOVA (Eriksen et al 2004). It seems clear that Swedish research has been a world leader with the result that Swedish- produced cars were the first to adopt these systems, see Appendix 5.
- Development of better protection against injury in the event of side impact. Again Swedish research has been at the forefront and the Autoliv company is now one of the worlds leading manufacturers of side impact airbags, see Appendix 5
- Swedish research has been significant in understanding the importance of speed for the consequences of accidents. It has also been important in understanding drivers actions and choices, their use of different types of information and their reactions to different forms of enforcement, see Appendix 6.

Swedish road safety research has also had some influence on what has happened in Sweden in a number of other areas. However, in these areas research in other countries may have contributed equally to the development of knowledge.

7.2 Calculating the contribution of various factors

The calculations are based on previous works by Brüde (1995 og 2005), Nilsson et al (2002), Nilsson (2004), Thulin (1987) and Thulin and Kronberg (1998) as well as easily accessible data from public statistics.

Total volume of travel and the share of modes of transport. According to Brüde (2005) the number of vehicle kilometres by motor vehicles increased from 37 billion kilometres in 1970 to 76,1 billion kilometres in 2004. The figure for 2005 can be estimated to 77 billion vehicle kilometres. Data on the volume of travel measured in person kilometres can be obtained from travel surveys. Nilsson (2004) gives the volume of travel by road in 1997-99 as 101 billion person km. Brüde (1995) has developed a simple model to explain changes in the number of fatalities over time. The model explains the number of fatalities as the product of exposure and risk. For the period 1977-1991 the following model was used for the data:

Number killed annually = $0.2091 \cdot 0.9562^{\text{year}} \cdot \text{Vehicle kilometres}^{1.851}$

Year is given the value 1 for 1977, 2 for 1978, etc. The coefficient for vehicle kilometres means that if the vehicle kilometres increases by 1 %, the number killed will increase by 1.5 %. Increasing travel therefore means that, all other conditions being equal, the number of fatalities will increase. This means that increased travel cannot explain an improvement in road safety. On the contrary, it is more correct to say that road safety is better despite the fact that the amount of travel has increased. The fact that the decrease could have been even greater if travel had not increased is not relevant here as it is the actual decrease that requires explanation

Even though increased travel is not favourable for road safety, changes may have occurred in the distribution between modes of transport and population groups that have had a beneficial impact on safety. We have compared results from studies of such changes using travel data from 1984-85 (Thulin 1987), 1992-95 (Thulin and Kronberg 1998) and 1997-99 (Nilsson 2004). The proportion of person kilometres travelled by pedestrians, cyclists, moped riders and motorcyclists went down from 6.7 % in 1984-85, to 5.3 % in 1992-95 and 5. 0 % in 1997-99. It is estimated that this has reduced the number of fatalities by 50. Furthermore the tendency towards fewer younger drivers has reduced the number of fatalities by 20 annually.

Construction of motorways and roads with median barriers. VTI (Nilsson et al 2002) has calculated that an increase in the proportion of vehicle kilometres on motorways from 18.9 % to 22.5 % of the total vehicle kilometres on national roads in the period from 1994-2000 reduced the number of fatalities by 10 annually. If we extrapolate this considering the increase in the length of motorways between 1970 and 2005, we can conclude that extending motorways in this period has reduced the number of fatalities by about 30 people annually. At the end of 2005 there were 1 190 km of roads with median barriers in Sweden (Carlsson og Brüde 2005). It is estimated that this has prevented some 30 deaths and around 120 serious injuries. All of this road safety improvement was achieved between 1998-2005.

Speed reducing measures in towns and cities. In connection with the case study concerning safety in towns and cities, we have calculated that the construction of roundabouts – which can act as an indicator of other speed reducing measures in towns and cities has reduced the number of fatalities annually by 40, see Appendix 3. Systematic testing of speed reducing measures in towns were implemented in Växjö from 1986, as part of a large trial that was carried out and evaluated by Lunds Tekniska Högskola (Hydén et al 1995 and 2000). The trial was originally very controversial and aroused great interest in the mass media. Today it is judged to have been highly successful and has served as a model for similar programmes in other Swedish cities. In Gothenburg comprehensive speed reducing measures were implemented after 1978 with faster implementation from 1990. The results in the form of a decrease in the number of fatalities and serious injuries are very good. (Johansson 2005).

Development and use of seat belts. Nilsson et al (2002) have calculated that increased use of seat belts in the period 1994-2001 reduced the annual number of fatalities by almost 11 persons. From 1970 to 2005 the annual number of drivers killed in Sweden went down from 370 to 192. Since the use of seat belts amongst car drivers in the entire period after 1983 was high - above 80 % (Cedersund 2006), it must be assumed that reduction in the numbers of drivers killed after 1983 is largely due to factors other than an increased use of safety belts. The largest part of the impact of increased use of seat belts was achieved prior to 1983.

Here it is assumed that the use of seat belts amongst car drivers has increased from 15 % in 1970 to 92 % in 2005. Drivers who do not use seat belts are involved in accidents more often than drivers who do use seat belts (Evans 2004). Based on the information given by Krafft et al (2006), it can be estimated that drivers who do not use seat belts are involved in fatal accidents 3 times more often than drivers who use seat belts. Furthermore, it is assumed that seat belts reduce the drivers' risk of death by 50 %. With these assumptions it can be calculated that increased use of seat belts from 1970 to 2005 has reduced the number of drivers killed by 110 annually. A similar reasoning leads to an estimate of 40 fewer deaths among car passengers as a result of the increased use of seat belts.

Development and use of safety equipment for children in cars. In the case-study for this measure, see Appendix 4, the impact for road safety of better protection for small children (0-3 years) in cars has been calculated. It is calculated that better safety for children in cars has reduced the annual number of fatalities by 16. The decrease in the annual number of serious injuries is estimated to 38. Sweden had an early start in developing safety equipment for children in cars. It took some time for the use of the equipment to be adopted. Today, usage is high and the benefit of the measure is clearly greater than the costs. Swedish researchers participate actively in the work to achieve international standard of the equipment that is recommended in Sweden and a number of countries are now using the Swedish model. Swedish authorities continue to work to ensure international impact.

Car crash worthiness. Based on an earlier study (Eriksen et al 2004) it can be estimated that the development of better protection against whiplash and better protection against side impact have reduced the annual number of fatalities by 10, see also Appendix 5. The entire decrease was achieved during the period between 1998-2005. VTI (Nilsson et al 2002) has calculated that increased use of airbags between 1995 and 2001 has reduced the numbers killed in cars by 29. The proportion of vehicle kilometres due to cars with airbags increased in the period from 15 % to 60 %. It is assumed that 90 % of vehicle kilometres by cars in Sweden in 2005 is due to cars with airbags. VTI's calculation shows that the impact of increased use of air bags has increased from 15 % to 60 %, i.e. 45 per cent. The effect of the increase in the use of airbags from 0 % to 90 % is calculated to be a reduction in the numbers killed in cars by 55 persons annually.

More effective police enforcement. From 1981 to 2004 the number of drivers checked by the police in Sweden increased substantially (Brüde 2005). The number of drivers checked per million vehicle kilometres is a measure of the risk of detection of traffic offences. An analysis of data for the period 1981-2004 indicates that the risk of detection has increased. An estimate of the effect is that this has led to a reduction in the numbers killed of around 150 persons annually, see Appendix 6.

7.3 The factors selected explain a large part of the decrease

The calculations that have been carried out are summarised in table 7.2. They are relatively rough estimates that only indicate the magnitude of the impact that the various measures have had. Estimates for the reduction in the number of fatalities have been rounded off for this reason. Altogether the factors that are included have reduced the annual number of fatalities in Swedish traffic by 550.

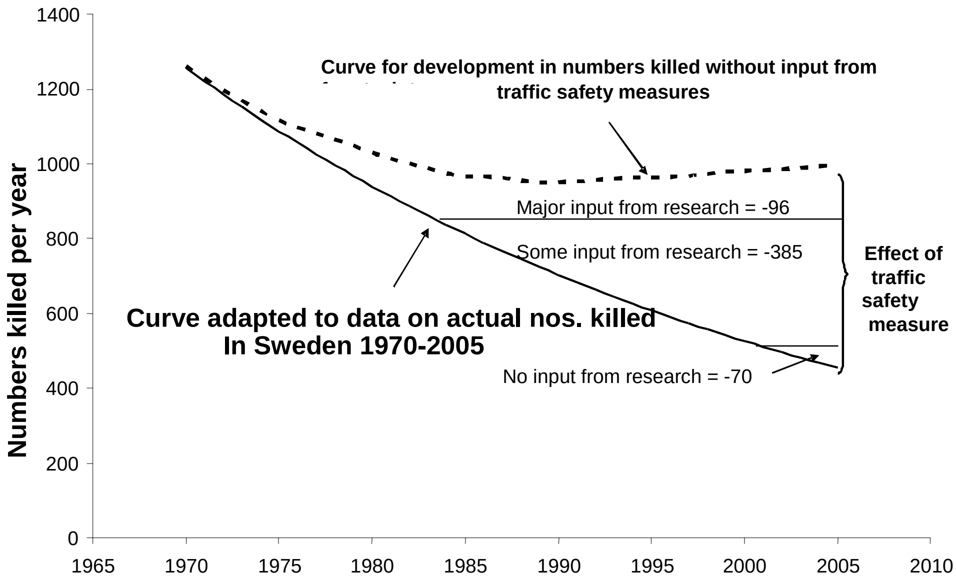
Table 7.2: Calculated impact of selected factors on the long-term development of the annual numbers killed in traffic in Sweden. Significance of the research for the factors is given. Measures related to this projects case studies have a blue background and measures related to exposure (not direct road safety) have a purple background

Factors that have affected road safety development	Significance of research for developing the measures	Calculated contribution to the decrease in the number of fatalities
Less pedestrian, cycle, moped and motorcycle traffic	No significance	50
Fewer young drivers	No significance	20
Expanding motorways	Some significance	30
Expanding roads with median barriers	Major significance	30
Speed reducing measures in towns and cities	Major significance	40
Increased use of seat belts amongst car drivers	Some significance	110
Increased use of seat belts amongst passengers	Some significance	40
Development and use of safety equipment for children	Major significance	15
Development of better protection against whiplash and side impact	Major significance	10
Other collision projection/ air-bags	Some significance	55
More effective police enforcement	Some significance	150
TOTAL		**550**

Figure 7.2 shows the curve fitted to the data in figure 2.1, together with a curve which indicates how the trend in the number of fatalities would have been if the factors for which impacts have been calculated had not contributed to reducing the number of fatalities. Even without the measures for which impacts have been estimated, some decrease in the number of fatalities in Sweden could have been expected, from an fitted value of 1260 in 1970 to an fitted value of about 1000 in 2005.

In addition, in figure 7.2 curves indicate whether the research has had major, some or little significance. It is estimated that measures which have been developed as a result of a large research input have reduced the number of fatalities by 96 annually. Measures where research has provided some input have reduced the number of fatalities by 385. Trends in factors which are only affected to a small extent, if at all, by road safety research is estimated to have contributed to an annual reduction in the number of fatalities of 70 people. All in all, it can be concluded that the number of fatalities in traffic in Sweden has been reduced far more than would have been the case without the road safety research.

Figure 7.2: Long-term development of number of fatalities in Sweden. A curve fitted to actual data and a curve showing possible trend when the impact of selected road safety measures has been removed[23]



Other possible factors which may have been effective but where we do not have sufficient knowledge about impacts, are:

- A large number of other measures on the road network, such as road lighting, guard rails, traffic signals, traffic management etc.
- Moving to new, safer residential areas; an increase in the number kinder-gartens that have reduced children's exposure to traffic.
- The driver population is on average more experienced.

Many other factors could also be included. On the other hand, some factors have also probably contributed to an increase, for example increased traffic, increased speed and an increased proportion of elderly drivers.

7.4 Research funding has gone to useful measures

Many of the road safety measures that have documented impact have been developed with the help of research. In order to show the extent to which VINNOVA and its predecessors and PFF in particular have contributed, we have categorised the projects in VINNOVA's database by type of measure.

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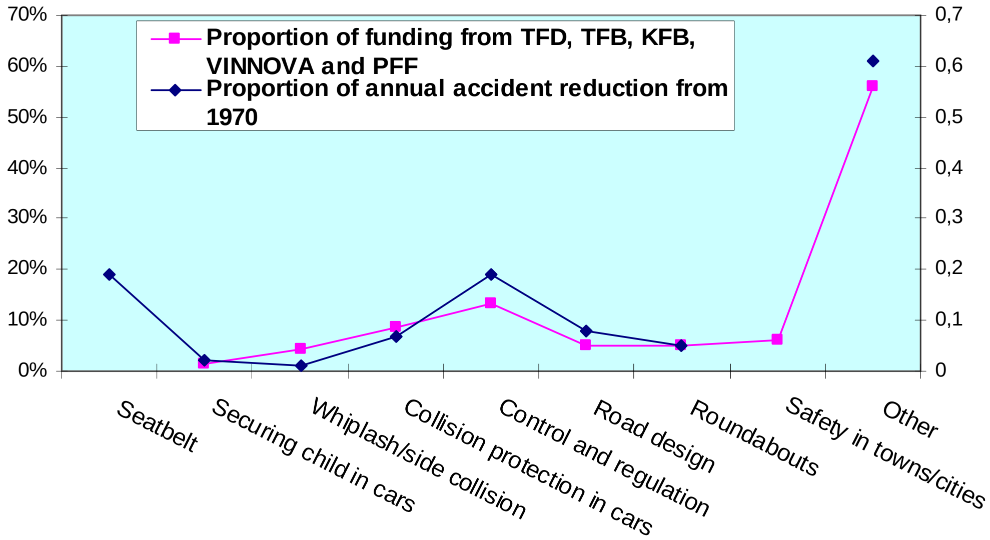
[23] The total number of those killed as the result of different measures we have used here does not take account of any interaction impact between different measures. A control calculation where estimates for such impact are included gives a somewhat lower figure but is of no significance for the conclusions in the report.

Here we have taken the types of measures where we have evaluated the impact as a point of departure, but used a somewhat broader framework for categorising projects. This also means that basic research and general methodological development relevant for the measure are included.

We have compared the proportion of projects in each category of measures with the impact calculations for key measures in each group. The result in figure 7.3 shows a good correspondence between input and output. In other words, this clearly shows that the contribution of the Swedish research funding bodies has had positive effects and that the focus has been on important project areas.

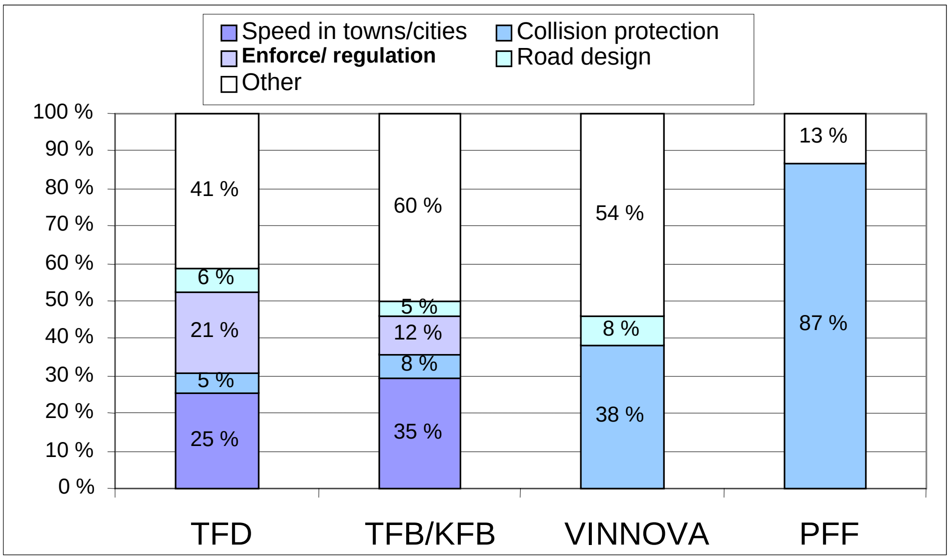
In the analyses we have included accident impact for seat belts even though much of the research input dates from before 1971. In addition we have shown that the research input for measures other than roundabouts and intersection design related to safety in towns and cities as a separate category, even though we have not calculated the exact accident reducing impact of these different measures. We know, however, that safety in towns and cities has increased significantly, see figure 8.1.

Figure 7.3:Calculated impact of road safety measures in relation to research input (number of projects) to groups of measures from VINNOVA and its predecessors and PFF in the period 1974 – 2004



In a system perspective, road safety work must be based on knowledge about vehicles, roads and different road user groups and the interaction between them. As shown in figure 3.2, VINNOVA and PFF have a different profile to their predecessors, While TFD, TFB and KFB covered the whole spectrum, VINNOVA and PFF have focused on technology development. 69 % and 87 % respectively of their funding goes to projects within this field. This is an important focus given the impact potential calculated up until 2019 (Elvik 2005). The difference between the funding bodies is also illustrated in figure 7.4 which shows the measures to which the different players' research support has been related. The challenge lies in ensuring research in other areas with a potentially greater impact on safety in Sweden, such as road investments and police enforcement.

Figure 7.4: Projects within different areas of measures of significance for safety funded by TFD, TFB/KFB, VINNOVA or PFF in 1974-2004 by area of measures of the projects. Proportion (N=434)



7.5 Summary – the benefit is greater than the costs

In a macro perspective, Swedish road safety research has proved to be extremely useful. Altogether, the 471 human lives that are saved that can be related to the research effort in the field of safety, represent an annual economic benefit of about SEK 8.2 billion, based on SIKA's (2005) evaluation of a human life as SEK 17.5 million. This far exceeds the half billion that VINNOVA and its predecessors has invested in road safety research in total and the approx SEK 200 million that was set aside for the effective measures for which we have calculated the impacts.[24]. If we include traffic injuries, the benefits are many times greater.

[24] Projects related to roundabouts/ intersection signs were allocated SEK 21.0 million; Safety in towns received SEK 25.4 million; Child car seats SEK 6.2 million; Whiplash/ side impact protection SEK 32.3 mill SEK; other Collision protection SEK 66.3 million; Enforcement SEK 37.0 million and Road related measures SEK 25.5 mill Research related to the area of measures is here interpreted liberally. e.g. here basic research into road user behaviour is linked to the enforcement field.

Similarly we see from a micro perspective in the case studies we could go into more detail into the costs of measures and the different elements in a economic calculation, see Appendix 3 - 7. The analysis here shows that the benefit clearly exceeds the costs. The most important results from the case studies can be summarised thus:

- It has been estimated that the speed reducing measures in towns and cities for Sweden as a whole have resulted in a economic benefit (present value) of SEK 17 billion and a total cost of SEK 6.9 billion. For Gothenburg, the benefit is estimated at SEK 8 billion and the costs SEK 200 million see Appendix 3.
- The benefit to society of better safety for children in cars is estimated to be SEK 1 350 million (present value), see Appendix 4. The costs are estimated at SEK 210 million annually, see Appendix 4 and section 6.4.
- The benefit of better whiplash protection (in new cars) is estimated to be SEK 1.9 billion, see Appendix 5 and the earlier whiplash study (Eriksen et al 2004). The development costs are estimated at around SEK 100 million and the additional costs for car buyers are estimated to be SEK 100 million.
- The benefit of side impact air bags is estimated to be SEK 4.6 billion (present value). The additional costs can be estimated at around SEK 1 270 million see Appendix 5 and section 6.4.
- More effective police enforcement is estimated to contribute to 150 fewer deaths annually. Police enforcement is different from the other measures in that benefits and costs are more contemporaneous. When enforcement is reduced or disappears, the benefit also drops off, in contrast to road investment and vehicle technology measures that have impacts lasting many years. The annual costs of police enforcement in Sweden are estimated to be around SEK 500 million (Elvik and Amundsen 2000) The benefit in the form of fewer deaths and injuries is estimated to be around SEK 3.4 billion see Appendix 6.

From the above it is quite clear that these measures are very profitable from a socio economic point of view. The measures that are dealt with in the case studies have a large net benefit, totalling around SEK 20 billion. The figure is not exact, given that it is difficult to calculate a total accumulated benefit over a number of years for all the different measures. This particularly applies to police enforcement where the benefit primarily occurs during the period when the enforcement is being carried out.

Where Swedish research has developed measures that save many lives and that have also been implemented elsewhere, the benefit of the research will be greater than the Swedish benefits indicate. We have not estimated this here, as such estimates would be very uncertain.

8 Development of knowledge in society

8.1 More indirect impact of research

As shown in section 1.3, research can have both direct and indirect impact. Distinctions can also be drawn between instrumental, conceptual and symbolic use. While the previous chapters have focused on the more direct impact and instrumental use, in this chapter we will deal with the conceptual and symbolic use of research.

Weiss and Bucuvalas (1980) observed two fundamental conditions for research being used (in one or other of the above definitions) by public decision makers: firstly that the research is seen as correct and secondly that it is seen as *relevant* in relation to the decision-makers' area of interest. Both these factors indicate that the users opinions and experiences play a major role in deciding whether research is used and that this does not simply depend on the nature of the research itself. Changes in the use of research may thus due to changes in user organisations.

Amara et al (2004) confirmed that, inter alia, the facts below have positive impacts on the use of research results.:

- Quantitative results
- Results adapted for application
- Relevance in relation to existing areas of work
- Long-lasting interaction between researchers and users
- How easy it is for users to obtain the information

This again shows that application depends on the characteristics of the research results, user characteristics and relationships between researchers and users For example there will be a greater chance of using commissioned quantitative research carried out by researchers who have a long-lasting relationship with the clients being used, while qualitative basic research projects carried out by independent researchers will have less impact.

Qualitative reports lead to conceptual use to a greater degree than quantitative reports and users with higher education are more liable to use research results conceptually than users with lower levels of education (Amara et al 2004). This means firstly that impacts of qualitative research may be difficult to measure. Secondly, this may also indicate that it is more natural to look for impacts of qualitative research in some organisations rather than others.

However, studies show that the main use of research is conceptual (Weiss and Bucuvalas 1980), and this is also the type of use that it most difficult to measure. We have therefore used analyses of documents and interviews to identify the influence of research on ways of thinking and on policy development both in Sweden and abroad.

8.2 Changes in thinking nationally– examples from the case studies

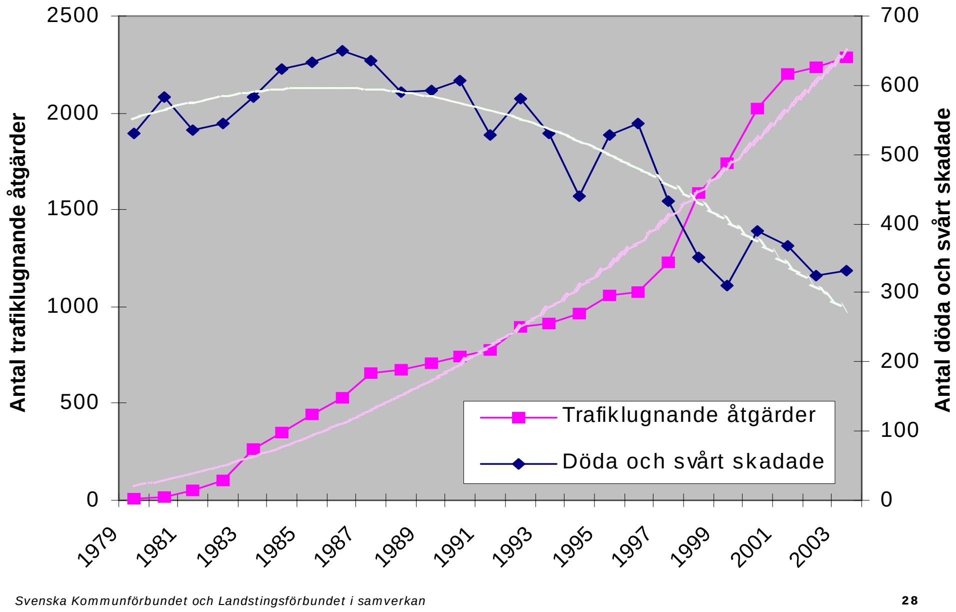
8.2.1 Speed reducing measures in towns and cities – an obvious success

Analyses of the long-term development show that from around 1975 to around 2003 the decrease has been a greater in the number of fatalities and serious injuries in towns and cities than in less densely populated areas in Sweden. Based on the analyses that have been carried out, it is assumed that the progress in road safety in towns and cities can be attributed to increased use of speed reducing measures stimulated by research that has shown that these measures are effective. The experience and achievements can be summarised in the following points:

- A comprehensive study of speed-reducing measures in Växjö, carried out by Lunds Tekniska Högskola, documented that roundabouts and stop signs worked well as speed reducing measures (Hydén et al 1995 and 2005).
- The Växjö- experiment aroused great interest amongst the mass media and was initially highly controversial. This stimulated interest in speed-reducing measures in general. Today the vast majority regards the Växjö experiment as highly successful.
- Gothenburg is amongst the larger Swedish municipalities that have systematically used speed-reducing measures to improve road safety. More than 2000 speed-reducing measures have been brought in since 1978. The numbers killed or seriously injured have gone down by 47 % from 1985-89 to 2003 (Johansson 2005).
- Inspired by these experiences and by Vision Zero, in 1988 Svenska Kommunförbundet issued the handbook entitled ”Lugna gatan!” This contains guidelines and advice for Swedish municipalities for reclassifying the road and street network and the use of speed reducing measures. The book has been a great success and many municipalities have used it in their road safety work.
- It can be estimated that speed-reducing measures in towns and cities have reduced the number of fatalities by 40 annually. This is a conservative estimate and the impact may actually be a reduction of 60 persons killed annually (from 1970 to 2005, as a result of all measures carried out in this period), see Appendix 3.

- The economic benefit of speed reducing measures in towns and cities clearly exceeds the costs of the measures. For Gothenburg the benefit is estimated at SEK 8 billion and the costs at around SEK 200 million.
- In Sweden today there is a high degree of support for speed reducing measures in residential areas. A large majority of the population states that such measures make traffic safer and less threatening and hence contribute to increased well-being

Figure 8.1: Annual number of fatalities and serious injuries compared with the number of traffic calming measures in Gothenburg . Research based development.



Source: Sveriges Kommuner och Landsting

Representatives for Gothenburg's traffic office believe that research based measures are a significant explanation for the positive development in Gothenburg. The following circumstances or facts have contributed to the focus on road safety in the last 10 years:

- Vision Zero. Research has succeeded in explaining relations such as the Crash Damage Curve in a way that people and politicians can act upon
- GNS – Gruppen for Nationell Samverkan where Svenske Kommuner och landsting (SKL), SNRA, Rikspolisstyrelsen, Nationalföreningen för trafiksäkerhetens främjande (NTF) and also The Ministry of Trade and Industry and car manufacturers all take part. This has established a common platform for road safety work, and for the development of knowledge.. Here the strength lies in the close link between knowledge and practice.

- SKL’s development of municipal road safety work. Since 1990 SKL has focused on disseminating road safety knowledge to the municipalities – at both the political level and to the officials in charge and in easy to understand and somewhat untraditional ways.

Traffic safety work in Gothenburg has been research-based *directly* through the projects where people have participated themselves and *indirectly* in that the implementation and evaluation has always been based on research results. . Gothenburg municipality has supported research both by contributing to the programmes (part funding) and by issuing statements of support. The work is carried out in close contact with Lunds Tekniska Högskola and SNRA.

This demonstrates how long-term co-operation between researchers and users leads to more effective use of research results. The co-operation ensures both that researchers are focused on the concrete problems that users want to solve and that users have a more thorough understanding of how research knowledge can be understood and utilised. Long-term co-operation can also contribute to changes in perspectives and to developing a common understanding of questions and problems.

At the same time the results show the importance of making research accessible to users and to the public in a pedagogical form. Both the demonstration projects and Vision Zero have been exemplary in the sense that they are easily understood by the user group and that they are sufficiently visible to attract attention from the press and the public. Town experiments are also an exceptionally good method for getting people to change their way of thinking, given that it is often difficult to argue that problems must be approached from another angle.

8.2.2 Child car seats –a basis for a new understanding of children and a new culture

Swedish research lies behind a groundbreaking innovation that has had major impact on the safety of children in cars, namely the rearward facing child car seat, see Appendix 6. The seat distributes the forces in an accident on the back of the seat rather than the child and with correct use there is a reduction in risk for children aged between 0 and 4 years of up to 90 %. The design was followed up by the authorities and manufacturers in Sweden and a few years later the seat went on sale and laws were passed to make use compulsory. Research by VTI on the use of the seats, led to the distribution of free seats to newborn babies at maternity units, which undoubtedly helped to increase usage.

The innovation also represents a revolution in the attitude to children in traffic in a wider sense. It became clear that children are not small adults and that they have different bodily and psychological abilities and traits. This has also been very influential in planning measures to protect children in traffic (see Sandels 1969). Since there are still many countries where this system is not in use, the potential for further benefits is obviously there. There is also potential to develop the systems so that incorrect use is avoided.

Mechanisms that contribute to explaining this success are:

- *The concept arose in an interdisciplinary environment* with good opportunities for testing different models. Technical, medical and behavioural research were all vital in understanding the problem, developing a solution and overcoming barriers in order to have an impact.
- *Knowledge alone is not sufficient to have an impact.*. The Transport Research Council emphasised the direct contact between research and practice. With members of relevant authorities on the council , it was possible to influence laws and regulations. Contact with the car- and equipment manufacturers also meant that production commenced fairly soon.
- When the institution where the innovation was made was closed down, *steps were taken to facilitate the continuation of the work in a number of institutions*; including both at VTI and Chalmers.
- VTI developed knowledge about measures to increase use and to *ensure the correct use of the product.*
- VTI also succeeded in creating a positive connection between testing and research that made it possible to collaborate on international standardising work and to develop new products, including the new ISOFIX fastening system.
- Chalmers for its part had close contact with Volvo Car Corporation, where research and development had being going on the whole time, even though Chalmers had focused more on whiplash injuries.

Again we can see that important determinants of success are co-operation between researchers and user groups. In addition it is important that the product is not regarded as ”finished” the moment the technical problems are solved, but that the research institutions are involved in an ongoing improvement process. VTI has realised that insufficient or incorrect use should not be considered as a problem separate from the technical problems but that attempts must be made to adapt the solution to the *actual* problem and not just the technical element. In this way researchers have worked actively to accomplish a cultural change, from the time when the rearward facing child car seats were a technical invention to the point where they are an obvious part of responsible child rearing.

The challenge is that it is hard for small countries to gain acceptance for their results where there is professional disagreement and where others have greater power in important decision making bodies. To influence and to pave the way for use of Swedish designs and products requires resources (scientific and financial in order to participate in important events) something to which VINNOVA and its predecessors has contributed.

8.2.3 Police enforcement - from basic research to practice

Until the transition to driving on the right in 1967, Sweden had no speed limit outside built-up areas. From 1967 speed limits were introduced, as a trial period until 1979 when speed limits were made permanent. During the period between 1967-1979, a number of speed limit trials were evaluated by VTI. These trials showed how important speed is for road safety and in due course led to the development of the so-called ”power model” for describing the relation between speed and road safety. (Nilsson 2004). This model is also recognised internationally. Gradually, it was realised that speeding is a major road safety problem. This formed an important part of the background for research into how effective police enforcement could be set up to reduce speeding.

The Department of Psychology at the University of Uppsala has for many years carried out research on the effect of various forms of police enforcement on driver behaviour , see Appendix 6. Together with other research in the field this research has contributed towards documenting the impact of enforcement and also to making it more effective.

- The case study demonstrates how fundamental, interdisciplinary knowledge of a field is necessary to be able to carry out effective road safety work.
- Police enforcement is one of the most cost effective measures in road safety work
- Swedish researchers have contributed to the knowledge that a visible police presence and police enforcement have accident-reducing effects.
- Knowledge about the relationship between subjective and objective risk of apprehension is decisive in designing the enforcement strategy.
- The research was initiated through a TFD-research programme.
- The research results were most effectively disseminated to the police through long-term co-operation but also through personal relations, seminars, conference and lectures.
- The police’s lack of expertise within research-based work may have been an obstacle for greater use or earlier use of the research results.

Again we can see that co-operation appears to be the most effective form of dissemination. Results have mainly been achieved when individuals have got a grip on the research results and worked together with the research community for long enough for entire police districts to learn to work in a more scientific manner, where attempts are made to establish the effects of various forms of enforcement.

Based on the research on police enforcement, police enforcement must now be ”evidence based” and given that the risk of apprehension changes behaviour, the number of police controls should be increased considerably. This shows that the police organisation has accepted the research results within the field, but it is perhaps even more important that the police organisation has accepted that it is possible to use research to develop more or less effective forms of enforcement.

Any dissemination problems can also be traced back to the user organisations, which do not always have the will or the expertise to make use of the available research based knowledge. As indicated earlier (see section 8.1) certain types of research are more widespread in organisations where the staff have an academic background, which may explain why it can be a challenge to disseminate research results to practicing “traffic police” who are not used to this way of working.

8.2.4 Side impact airbags – major commercial impact

Side impact protection and airbags have been important products in the service of road safety in the last ten years and have also been important for Swedish manufacturers of side impact airbags and other advanced side impact protection. For Swedish car manufacturers, the value of safety equipment like side impact protection consists primarily of the fact that Volvo and SAAB are regarded as attractive and safe cars.

Research at Chalmers Tekniska Högskola has been and remains central in the development of safety equipment with a broad spectrum of products. Co-operation between researchers, funding institutions and industry has proved to be effective and to result in new, creative solutions for the Swedish car manufacturing industry.

The financial contribution to basic research from VINNOVA and its predecessors has been and remains a catalyst that initiates this co-operation and contributes to product development and added value for the Swedish manufacturing industry. As well as creating qualitatively good research institutions, this has also helped to strengthen the Swedish car manufacturers' competitiveness in the international market and to the development of completely new products and enterprises.

8.2.5 The simulator as a tool for research and practice

There is little doubt that VTI's driving simulator has been of major significance for the volume and direction of road safety research at VTI, and hence for Sweden, see Appendix 7.

The driving simulator has made it possible to carry out experimental studies on questions that are difficult to study using other methodological approaches. For topics such as road design, road signs and road markings, and equipment in cars, the alternative to using a simulator is to carry out field studies, which are very resource-intensive. The simulator has also made it possible to study different impairments amongst drivers, such as illness, use of medication, fatigue and the impact of alcohol, which for legal and ethical reasons can be difficult to study in other ways. Also, for the collection of information on human qualifications and limitations for safer driving, of example the study of mental and visual overload, the simulator has provided knowledge which otherwise would be difficult to obtain. However, staff from the Swedish roads administration are concerned about the cost of its use. Many opportunities for use have been identified, but in practice only the major road projects can afford to use the simulator.

Users from both business and manufacturing highly value the opportunity to use the simulator (see section 6.5). The car manufacturing industry has also been involved both as a provider of funding and as a cooperative partner in a number of projects A number of studies have been carried out with the car manufacturers in addition to those which are identified in published works.

The simulator is an example of a form of technology in which investments have been made, despite the fact that it has not had any immediate beneficial effect and is thus an example of a more long-term strategy for research funding. It has been essential for both scientific work at a high international level and for carrying out important studies on road safety. Co-operation between researchers, authorities and industry has contributed to its potential being utilised to a relatively high degree.

8.3 Contribution to international policy development

8.3.1 The EU's policy documents

It can be problematic to estimate the significance of Swedish transport safety research from analyses of the EU's policy documents. The documents are not scientific publications and hence do not use traditional scientific referencing systems. Often no reference to sources are given at all, while the references in other contexts are often so inadequate that it is difficult to trace the primary source. Hence comprehensive background knowledge will often be needed in order to identify the sources for the individual statements or ideas. The documents are also a mixture of presentations of the status quo, research results and plans for future road safety work. The extent of Swedish influence on the documents cannot therefore necessarily be determined by quantitatively stating the proportion of Swedish references or ideas However a closer study of the documents does give some impression of the Swedish position within the EU with regard to road safety, and of Swedish influence in international policy and agendas in this field.

In the EUs' *White Paper* on European transport policy part III deals with road safety. Sweden is mentioned in this chapter with regard to its impressive road safety statistics in connection with Vision Zero (specifically in relation to safety requirements in public transport contracts) and in connection with the high proportion using seat belts.

A simple search shows that the EU's action programme for road safety from 2003, *Saving 20 000 Lives…* mentions the word Sweden in 4 contexts:

- In connection with being (together with the UK and NL) one of European countries with the best road safety and also amongst the first to set quantitative targets for the reduction of road accidents
- In connection with the fact that Vision Zero has inspired several Swedish local communities to include road safety requirements in contracts for public services such as transport services and vehicle purchase.
- in connection with the fact that Sweden has Europe's highest level of safety belt usage but also that 50 % of fatalities in road accidents did not use safety belts
- as one of the countries that have carried out experiments with ISA, which should be studied by the EU in order to evaluate the optimal conditions for the use of the systems

Even though the majority of these references do not explicitly deal with Swedish research, it is nonetheless clear that they refer to a research intensive system, where risks and effects are well documented and where new methods for preventing road accidents have been developed and researched. In general, Sweden stands out in these documents as a leading nation within road safety that the rest of Europe can use as a model for its own road safety work. Sweden stands out as safe, rational and well documented. It represents a system that functions well where the different elements support each other.

In addition, there are references to measures or technology presumably based on Swedish research, where neither nationality, institution or individuals are named. These are not easy to identify and no guarantee is given that the list is complete:

- directives on front and side impact protection (p.25), must be assumed to originate in the Swedish- developed systems for protection against side impact.
- Standardised fastening mechanisms for child seats (ps.27) describes the Swedish- developed standard ISOFIX.
- The safety measure”daytime running lights”(pp. 31 & 33) developed in Sweden and elsewhere is described as effective, even though there is some uncertainty about the economic benefits due to the energy costs..
- The expression “forgiving road environment” (p.35) was coined in Sweden for one of the concepts in Vision Zero.

In general therefore it can be said that Sweden and Swedish research are highly visible in these documents and are visible in a definitely positive sense.

Perusal of the EU’s action programme for road safety also gives the impression that some of the Swedish ideas about road safety have had a major impact, perhaps mostly the ideas that form the basis for Vision Zero. For example on page 11 of the programme for action there is the following:

> *“Since human beings frequently and inevitably make mistakes, the system of infrastructure, vehicles and drivers should be gradually adapted to protect users more effectively against their own shortcomings. This is the approach in other modes of transport and safety at work”.*

Both the system perspective and comparisons with other branches of transport and with the work environment in general are argumentation strategies that can be recognised from the discussion pertaining to Vision Zero in Sweden, even though no specific reference is made to this. Similarly – and even more clearly – it can be seen that the Swedish slogan in Vision Zero “delt ansvar” has also been taken up in the EU in the form of the subtitle “Shared responsibility”. At a more concrete level, the report states that the European Commission will also try to encourage the spread of the Swedish model where road safety requirements are included in contracts for public services (p. 16).

The document CARS 21 (*Competitive Automotive Regulatory System for the 21st Century*) is not explicitly a road safety document but deals with the regulative framework for the European car industry. However, road safety is dealt with here in one chapter and in addition to specific recommendations and road maps that the group behind the report recommends a "holistic, integrated approach involving vehicle technology, infrastructure and the road user" (p. 33). Again this is a form of safety thinking that has much in common with Vision Zero and its focus on unity, system and interaction between the different parts of the road traffic system. In addition they recommend the Swedish safety measures of *daytime running lights*, ISOFIX and seat belt reminders.

The EU's frameworks programmes also show traces of this development. In the EU's 6th framework programme road safety was one aspect of "*Sustainable surface transport"*, and the research work within this field was presented as "advanced design and production techniques leading to improved quality, safety, recyclability and cost-effectiveness".

In general therefore it can be said that while the general Swedish level of visibility in EU documents is relatively good, the implicit visibility is far better. Many of the documents recommend measures and technology that have been developed in Sweden. Even more important is the fact that Vision Zero has contributed to changing the European safety discourse.

8.3.2 Benefits to "the Community" - Analyses of the EU's Internet pages[25]

In today's society, organisations' internet pages are central channels for communication with the public. In contrast to policy documents, internet pages are often read by a large audience without a professional interest in the themes under discussion, and thus the organisation's ideas are disseminated to a much larger public than is the case with traditional channels of communication.

Given that internet pages have a somewhat different function to documents, they cannot simply be understood from the same framework. Like documents, internet pages should deliver facts and relevant information to a number of different professional players, but a significant additional task is to communicate insights, overviews and the organisation's "image" to a wider public. Presumably, the most central and visible parts of an organisation's internet pages will to a lesser extent deal with technical details for the experts, but will rather try to set out the organisation's structure and strategies.

On the EU's internet pages, "Road Safety" is one of 10 sectors listed under the theme of *Transport*. The fact that road safety is presented as a separate

[25] Here we refer to the English language version of the EU's internet pages, as these are probably the most visited.

sector, and not as a subgroup under Road Transport may be taken as an indication of the increasing importance of road safety within the EU-system. The main page on road safety begins with the following paragraph:

> *"Every EU citizen has the right to live and work in safety. So, when you are walking, cycling, biking or driving a car or a truck, you should do so with a minimum risk to be hurt or killed. Likewise, other road users should not be damaged by your own participation in traffic".*
> (http://ec.europa.eu/transport/roadsafety/index_en.htm.)

Again this is a type of rhetoric that has often been linked with Vision Zero that in turn has often been formulated using similar terms

The text continues with a presentation of the EU commission's work on road safety. The activities are categorized as *Behaviour*, *Vehicle* and *Infrastructure* respectively. In addition the main page also presents the strategy documents discussed above and reference is made to the EU's information sources and research programmes within the field. Little is said – apart from the EU's list of information sources– about research results on this page. Going further into the website to the pages that describe the EUs road safety in relation to areas of activity, there are mainly descriptions of activities at the commission level, such as directives, hearings and programmes. However under the thematic area of "infrastructure", "forgiving road sides" are described in line with Vision Zero.

8.4 Topics and measures where Swedish researchers excel internationally

Through international publications, knowledge is spread internationally – not only to academia but also for practical use. In order to illustrate this, we have looked at the proportion of Swedish references in the most comprehensive review publication in the field of road safety, namely, the Norwegian Traffic Safety Handbook. The book has been published in Finnish, Russian, English and Spanish. Of the handbook's 124 measures Swedish researchers are responsible for more than 25 % of the studies that are included in the meta analyses for a total of 14 measures, see the overview in table V.4, Appendix 2. This must be seen as an impressive achievement for a small country like Sweden.

We have also looked briefly at the type of measures that the Swedish researchers have focused on in relation to the presumed benefit value. One example is taken from the handbook's chapter on Road Design and road equipment given in table V.5 in Appendix 2. We see firstly that Swedish researchers are well represented and have contributed studies that are included in meta analyses of impact of many measures. Secondly we see that they have contributed substantially in areas with major accident or injury reducing effects. These include for example Bypasses, Design of intersections, Roundabouts, Improving Visibility, Parapets and Road Lighting.

Asked to indicate areas where Swedish researchers excel, staff from DG TREN[26] and ETSC[27] mentioned *ISA (Intelligent Speed Adaptation)* because Sweden is one of the few countries that have carried out research in this area, and the EU's action programme stated that further research in needed in this area, especially with regard to behavioural adaptation. Infrastructure, accident analysis and vehicle technology were also mentioned as important areas of Swedish expertise.

Results of Swedish road safety research that were highlighted as particularly important were *daytime running lights*, *median barriers* on minor roads (2+1 roads), practical use of *alcohol specific interlocks* and ISA, and perhaps most important of all, Vision Zero. This is regarded as a sort of flagship for Swedish road safety thinking. Vision Zero succeeds – in clarifying Sweden's position within the field, not only because of the guidelines as such but also because of its high level of ambition. The representative for DG TREN pointed out that an unintentional message in Vision Zero is that Sweden is one step ahead with regard to road safety; while the rest of Europe is fighting for a reduction in the number of deaths of 50 %. Sweden's ambition is a 100 % reduction.

Neither of the two informants were willing to indicate areas where Sweden was lacking in expertise, either due to lack of knowledge about Swedish research input or because in comparison with many other EU countries Sweden appears to excel in the majority of areas. However, the representative for ETSC stated that for expertise within road safety work at the local level, he would have consulted Dutch researchers, as their concept of *Woonerf* was, in his opinion, the best developed in Europe. Similarly he would also consult Dutch researchers for information about road categorising.

8.5 Vision Zero as a European paradigm

The tendency for Vision Zero - or safety philosophies with much in common with this - to become more central within the EU system has been con-

[26] DG TREN (*Directorate General for Energy and Transport*) is the EU-organ responsible for development within transport and energy policies, and funds and organises much of the EU funded research within the area of road safety.

[27] The European Transport Safety Council (ETSC) is an independent organisation that works in conjunction with European decision makers (at a national and super national level) to promote road safety. The organisation is funded by membership organisation, by funding from the EU commission and by sponsorship funding.

firmed through interviews with representatives for the European Transport Safety Council, who stated that Vision Zero had strongly influenced the general discussion of road safety, and that to an increasing degree it was setting the premises for all European road safety work. This change was so marked that he maintained that Vision Zero thinking had led to a completely new conceptual understanding of road accidents: where previously accidents had been regarded almost as “Acts of God”, today it is seen that it is possible to prevent them and that accidents are a problem that can be solved over time. Vision Zero is therefore in the process of becoming a European paradigm

Similarly the WHO in its *World Report on Road Traffic Injury Prevention* (WHO 2004) describes a new road safety paradigm that largely resembles Vision Zero. This type of paradigm shift requires a major shake-up within the thinking on road safety, and will probably have major practical consequences over time, and must therefore be regarded as a very significant impact of Swedish involvement..

For the EU bodies, it is clearly not possible to acknowledge that one country’s policy has been guiding the EU’s overall policy strategy within the area, so it is not possible to confirm this through interviews, but the analysis of documents above appears to support the influence of the Swedish way of thinking.

Both informants from the EU system stated that the area of road safety in general had had greater impact and aroused greater interest within the EU over the course of the last five years, so that today the theme is more central than was previously the case, and it is easier to draw attention to or to make an impact with new measures.

A conspicuous trend in how both informants described the system was that measures could in a certain sense be understood as having been ”tested out” in Sweden. Both described how many - if not the majority – of new road safety measures had already been implemented in Sweden and were first introduced into the EU after the measures were evaluated in a Swedish context.

Traffic safety and road safety expertise were thus regarded as significant Swedish exports by the informants. Within the field, Sweden and the Swedes are seen as leaders and thus have a significant opportunity to be influential. In a certain sense it can be argued that Swedish accident statistics speaks for itself, so that the basis for the Swedish reputation in the field can be explained by this fact alone. However, this does not seem very plausible given that two other EU counties have almost identical accident risks and it would also be possible to maintain that the implementation of road safety measures is easier in Sweden, since it is a relatively small country.

It was also notable that the informants, even though they stressed the low Swedish accident risk, attached more importance to other factors when it came to explaining Swedish influence within the field. Alongside a number of effective *political* players (it was stated that a special element of Vision Zero was that it had also been spread via Swedish members of the EU-parliament, which is unusual for road safety innovations), it was pointed out that Swedish researchers had been successful in influencing the agenda in supra-national fora. This can be done through participation in research projects but also in other contexts such as conferences, seminars and strategy groups. SNRA in particular was highlighted for its ability to profile Sweden and Swedish road safety research internationally. SNRA's head of road safety was described as a very important individual in this context who has often talked about Vision Zero in international fora.

The representative for DG TREN mentioned several routes for Swedish influence on European road safety policies. Firstly the impressive Swedish accident figures mean that Sweden has a special impact in the *normal* political dialogue taking place in the European council. Swedish experiences and viewpoints in the field are seen as both central and important. A second point is that the Swedish member of the European parliament transport committee has been very active in promoting Swedish views on road safety. At the request of the European Council, a "High Level Group on Road Safety" has been set up, where both SNRAs head of road safety and the Swedish Minster of Communications are members. This group has had considerable influence (including the development of research programmes), and is an important forum for the exchange of experience from practice, innovations etc. Here as well, Sweden has had a major impact due to its solid reputation within the field..

8.6 Summary - road safety as a Swedish "branded good"

Sweden's reputation within road safety is longstanding and was previously primarily linked to Swedish cars. Today however, car manufacturers have lost much of theirlead, but Sweden excels within other areas such as infrastructure, legislation, follow-up and foresight.

However, in both the literature survey and in the interviews it can be seen that not only the research results but also the Swedish road safety discourse has had major influence in the EU and it can be said that road safety forms an important part of the Swedish branded good in this context. It is well known within the EU system that Sweden possesses broad expertise and good results within this field. Even though part of this reputation may be seen as political (given that it is also a question of the will to implement safety measures) rather than research driven, it would be unnatural to separate these elements from each other. Sweden has been in a position to carry out a successful road safety policy partly due to the fact that the policy has built on solid research. Relatively wide ranging road safety decisions have been adopted because it has been possible to document major impact. In this context, the Swedish system can be descried as a ”good circle”.

It is also the fact that the Swedish road safety system is research intensive which makes it easy to export – the research guarantees that the results can be understood as being universal rather than local, in that all the measures are rationally grounded and all the effects are documented,. As indicated by the representative from DG TREN Sweden is one of the counties where it is known that road safety measures are not just promulgated as laws but are also implemented and evaluated. The Swedish success is explained by a mutual reinforcement system where policy is built upon research results and the policy and its results are continuously assessed and evaluated by research.

Similarly the informant from ETSC stated that the Swedish road safety success must be see in connection with the fact that the policy has been based upon solid research. In the same way, the other SUN-countries (Great Britain and The Netherlands, which together with Sweden stand out as having Europe’s’ lowest road accident risks see figure 2.1) have solid research institutions and traditions within the field. The basis of this successful policy appears – according to ETSC – to be broad knowledge of the causes of accidents or injuries that in turn make it possible to implement preventative measures in a rational way. The rationality in the system is thus an important reason for Swedish international influence within the field, and this rationality is contingent upon solid and reliable research environments. Thus it is natural to see Swedish discourse within the area as partly research-driven. The political level depends on continuous research and evaluations of the system.

PART III – Reflections

9 Summary of impacts

9.1 Funding from VINNOVA and its predecessors and PFF has had impacts

The impact analysis of Swedish road safety research that is presented in this report applies to the period 1970 – 2004. Overall, road safety in Sweden improved considerably in this period. The main trend in the development is that the number of fatalities has gone down by about 67 % and the number of serious injuries by about 45 % between 1970 and 2005. Bearing in mind that road traffic during this period increased by 100 %, the risk of being killed or injured in traffic in Sweden has gone down by more than 80 % and 50 % respectively.

The Swedish society has invested relatively large sums of money in road safety research for many years. In all, a total of SEK 0.5 billion has been granted by the research bodies TFD, TFB, KFB, VINNOVA and PFF in the period 1974 – 2004. The reorganisation of the funding system in 2001 was intended to lead to closer co-operation between research and industry and seems to be successful. We see a clear tendency towards a thematic shift in the research effort towards a more technology- or industry- related perspective.

Safety research has been centred around a handful of central research institution belonging to the university or institute sector: Chalmers, VTI, Lund University and the Department of Psychology at the University of Uppsala. The four research institutions that have received the lion's share of funding from VINNOVA and its predecessors and PFF, have focussed on relatively different thematic areas. This breadth has provided a research basis for measures directed at the various different elements that make up a traffic system.

Over the years several evaluations of Swedish road safety research have been carried out. Based on these and our own analyses we can conclude that the funding from VINNOVA and its predecessors and PFF has made it possible to establish a number of strong Swedish research institutions in the area of road safety from the 1970s onwards. Funding from VINNOVA and its predecessors has provided means for research in both universities and institutions and for both disciplinary and inter disciplinary research. The quality of the research is of high international standard, is disseminated internationally and the players take part in international organisations.

9.2 Obvious benefits at the macro and micro levels

From a macro perspective, Swedish road safety research has proved to be extremely useful. Annually 481 lives are saved in Sweden because measures based on research have been implemented. This represents an annual economic benefit of about SEK 8.4 billion, based on SIKA's (2005) valuation of a human life as SEK 17.5 million. This far exceeds the half billion SEK that VINNOVA and its predecessors and PFF have invested in road safety research and the approximately SEK 200 million that has been set aside for research related to the effective measures for which we have calculated impact, see section 7.4. If we take traffic injuries into account, the benefit is many times greater.

From the micro perspective of the case studies, we find that:

Speed-reducing measures in towns and cities in Sweden have resulted in a economic benefit (present value) of SEK 17.1 billion and a total cost of SEK 6.9 billion. For Gothenburg the benefit is estimated as SEK 8 billion, and the costs as SEK 200 million.

- The benefit to society of better protection of children in cars is SEK 1 350 million (present value). The costs are calculated as SEK 210 million annually.
- The benefit of better whiplash protection (in new cars) is SEK 1.9 billion while the development costs are estimated at about SEK 100 million and the additional costs for car buyers at ca SEK 100 million.
- The benefit of side impact air bags is SEK 4.4 billion (present value). The additional costs can be estimated as around SEK 1270 million.
- More effective police enforcement has led to 150 fewer fatalities annually. The annual cost of police enforcement in Sweden is around SEK 500 million. The benefit in the form of fewer fatalities and injuries is around SEK 3.4 billion.

These measures are economically very profitable and have a major net benefit, amounting to around SEK 20 billion in total. The figure is not exact, given that it is difficult to calculate a total accumulated benefit over a number of years for very different measures. This particularly applies to police enforcement where the benefit primarily occurs during the period when the enforcement is being carried out.

If we add the annual benefits for the Swedish consumer/ Swedish society for whiplash protection and side impact air bags to the benefits for manufacturing, we obtain a total annual benefit of around SEK 1.7 billion. Where

Swedish research has give rise to measures with documented effects and which are also implemented elsewhere, the benefit of this research will be even greater than the Swedish benefits would indicate. These benefits are not included here.

The case studies also show that public funding that has gone to these projects has been useful for manufacturing. Financial support to manufacturing has been of sufficient volume to contribute to results, but it is not possible now to pronounce on the input-additionality of such support many years later. There are examples both of manufacturing increasing its contributions due to public funding and of projects being carried out even when the funding has been less than expected.

Extensive research collaboration has developed both nationally and internationally. There are therefore reasons for maintaining that the funding has affected the extent of co-operation in a good way, i.e. has had high behavioural additionality. It is also claimed that Swedish safety research has been very important for and may well have been decisive for the fact that cars and equipment are still being manufactured in Sweden. Significant economic impact of safety measures in cars have also been documented. This type of end impact of a long-term focus on safety research demonstrates substantial benefits and hence high output-additionality.

In addition to the research results, the Swedish road safety discourse has had major influence in the EU and it can be said that road safety stands out as an important part of the *branded good* Sweden in this context, see section 8.3. It is well known within the EU system that Sweden possesses broad expertise and good results within this field. Sweden is regarded as one of the countries where it is known that road safety measures are not promulgated as law but are also implemented and evaluated. The Swedish success is explained by a mutual reinforcement system where policy is built upon research results, and the policy and its results are continuously assessed and evaluated by research.

The basis of this successful policy must be thorough knowledge of the causes of accidents or injuries that in turn make it possible to implement preventative measures in a rational way. The rationality in the system thus becomes an important reason for Swedish international influence within the field, and this rationality is contingent upon solid and reliable research institutions. Thus it is natural to see the Swedish discussion within the area as partly research driven. The political level depends on continuous research and evaluations of the system.

Briefly summarised, on the basis of this impact analysis, it can be maintained that Swedish road safety research has had a significant impact on the development of road safety and the vehicle manufacturing industry in Sweden and that this impact would very probably not have been so positive without the long term, broad investment in this type of research that has been provided by TFD, TFB, KFB, VINNOVA and PFF. Public research funding has provided additionality in all areas, i.e. increased contributions from other sources of funding, a focus on safety in important research institutions and a range of impacts on society.

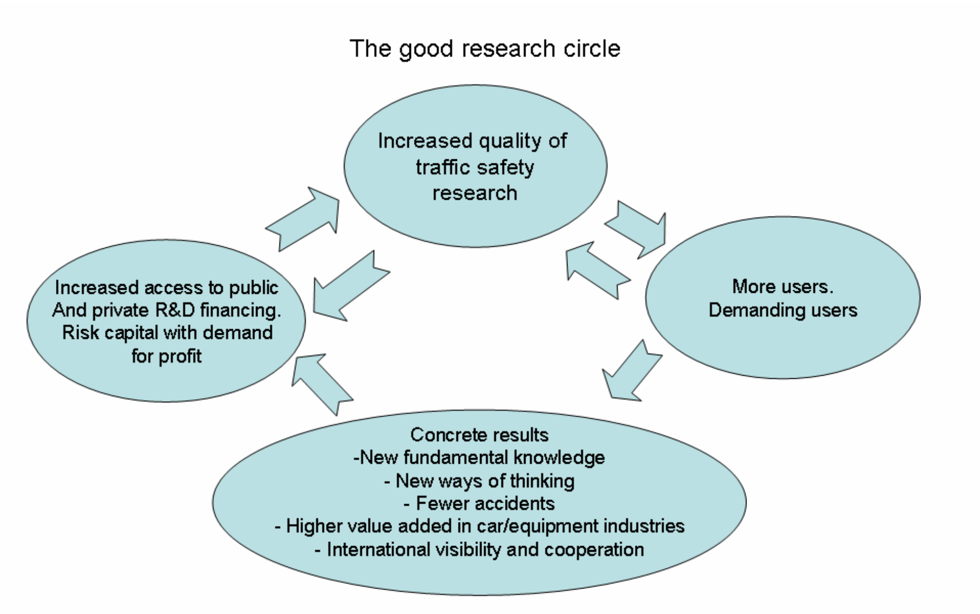
10 A good research circle

10.1 Swedish road safety research – a good example

Traffic safety in Swedes is extremely good, both compared with what is was around 1970 and with what it is today in other countries with a high level of motorisation see section 1.1. There is no doubt that road safety research and research-based road safety measures have been important factors. Swedish research has also contributed to the value added to the car-related manufacturing industries and through its high quality to policy development in the area of road safety both nationally and internationally.

Hence we can talk about a particularly high degree of output additionality, see the analysis model in figure 1.1. What are the factors or links in the chain of impact that have contributed to this? What makes what we call a good research circle? In figure 9.1 we have tried to illustrate some important feedbacks.

Figure 10.1: An illustration of a good research circle with impact for society and for industry



High quality of research is a necessary condition for creating a good research circle. This is often underrated in discussions of what contributes to innovation and creative processes. Where integration of measures contributes to developing high quality research, spin-offs are made possible at all stages. High quality generates both more users and more demanding users, which will motivate the research institutions to raise the quality even further, With high quality research and users who have an understanding of the importance of basing their choices, strategies and actions on research knowledge, the probability of good results for society and for industry also increases. Good mechanisms for making the results and the impact visible create better opportunities for increasing the funds for research and innovation.

Elements that characterise the Swedish safety research effort:

- An appreciation of knowledge and tradition for the systematic evaluation of measures in the area of road safety among Swedish politicians and authorities, i.e. those who for almost sixty years have ensured that public resources are set aside for road safety research.
- The development of highly competent research institutions that between them cover the most important areas of knowledge within road, road-user and vehicle interaction that cause road accidents and the serious consequences thereof. The Swedish authorities have thus been able to obtain tools to be able to manage road safety from a systems perspective.
- The funding systems have continued to develop networks and arenas for learning and interaction, leading to highly competent users in administration and in industry, a demand for research and hence ensuring that important knowledge is actually turned into practice in administration and industry.
- The Swedish funding system and networks have also contributed to the diffusion and dissemination of knowledge to the whole of society, which have helped to change ways of thinking, and contributed to scientifically-grounded vistas and strategies for road safety work.

10.2 What has made a good research circle?

The good research circle illustrates the significance of quality. Research institutions' self evaluations, our interviews with research institutions and users, the five case studies and experiences from similar impact analyses in other countries indicate some important prerequisites:

- Focus on increasing expertise through (1) funding for the educational system and basic research combined with (2) incentives to ensure that the discipline-based research staff at universities and colleges choose to work with road safety in their research, their doctoral degrees and their teaching. The funding arrangements have ensured that working within safety research is prestigious. The public research bodies have fulfilled a responsibility that industry would not or could not have fulfilled in the same way.

- Competent, non-bureaucratic support for researchers and research institutions has clearly been important in getting the best possible return for the input. All the Swedish institutions we have studied say that simple, competent executive work is an important characteristic of VINNOVA and its predecessors and PFF.
- The research institutions emphasise that during the period 1971-2000 they had relatively stable and predictable budgets over time, for example through theme programmes rather than funding for individual projects. Funding has been available during critical phases when other sources of funding did not have funds or or did not show any interest.
- The breadth and extent of the effort from 1971 have paved the way for inter disciplinary innovation and for interaction rather than competition. The breadth indicates a willingness to take risks that has paid dividends. Breadth means that there are greater opportunities for dealing with unexpected needs for knowledge as and when they arise.
- Making impact visible in a form that the funding authorities can understand, for example through economic measurements of results, has helped to demonstrate the relevance of research. This has been an important way to increase funding.
- Good contact with the whole user spectrum has enabled practical and political barriers to implementation to be overcome. Contact with the user environments will also help research results to be ”packaged” in a suitable way.
- Good circle effects are also to be found in the funding given to international activity and participation. This has stimulated improvements in quality, which in turn have resulted in spin-offs both nationally and internationally.

The good research circle illustrates the need for an agency with the main responsibility for the integration of measures. Our main impression is that VINNOVA and its predecessors and PFF have in many ways facilitated a good research circle. Since KFB was closed down in 2000 there is no longer one single authority with the main responsibility for Swedish road safety research. This creates new challenges.

The complementarity of the four key institutions means that the reorganisation of the funding system has had different impact for the different institutions. However there seems to be a shared opinion that it is more difficult than it was previously to obtain funding for long term and basic research. The research institutions that we have interviewed express some concern for the long term development of basic knowledge and theories within road safety in the years ahead and for funding doctoral degrees in the area. Funding for such activities has provided incentives for university institutions to invest time in road safety. Whatever the institution they come from, the interviewees state that funds are needed for behavioural and planning related research.

For 50 years, a single agency with the main responsibility for Swedish road safety research has ensured that there are no holes in funding of long term research, or for important parts of the integrated approach that is needed in order to be able to understand and manage road safety in a systems perspective. Sharing the main responsibility between VINNOVA and SNRA will set new demands for co-operation between the players, if the breadth and long-term nature of research are to be ensured in the best possible way.

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References related to the case studies are included in Appendices 3-7.

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SM/1764/2006: Traffic safetysutviklingen i Sverige og researchens mulige bidrag til den

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SM/1797/2006: Case study: Utvikling og bruk av VTIs kjøresimulator

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SM/1815/2006: Sidebeskyttelse i bil

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Appendices

Appendix 1: Overview of interviewees and dialogue partners

Appendix 2: Tables and overviews of the Swedish contributions etc

Appendix 3: Case study – Speed reducing measures in towns and cities, including roundabouts

Appendix 4: Case study – Developing and standardising backward-facing child seats in cars

Appendix 5: Case study – Developing better protection against whiplash injuries and side-on impacts

Appendix 6: Case study – More effective police enforcement/ police monitoring of speeding and drink driving

Appendix 7: Case study – Development and use of VTI's driving simulator

APPENDIX 1:
Overview over interviewees and dialogue partners

Appendix 1: Overview over interviewees and dialogue partners

Name	Title/area of responsibility
Vägverk centralt (The Swedish Road Administration)	
Thomas Lekander	Traffic safety analyst
The Swedish Road Administration Region Stockholm	
Mats Broman,	Head of Department of Traffic Safety and Environment dept. planl Södra Länken in Sthlm, use of simulator
Per Erik Wikström	Traffic safety strategy, Department of Traffic Safety and Environment
Therese Malmström	Department of Traffic Safety and Environment
Vägtrafikinspektionen (The Road Safety Inspectorate)	
Lars Bergfalk	Head of The Road Safety Inspectorate
Hans Rydgren	Analyst responsible for R&D
Sveriges kommuner och landsting SKL (The Swedish Association of Local Authorities and Regions)	
Jan Söderström	Senior manager, former head for Dept. of tillväxt och samhällsbyggnad.
Sara Hesse	Manager, Dept of tillväxt och samhällsbyggnad. Works with questions of traffic safety
Local authorities, Göteborg municipality, traffic office	
Lennart Adolfson,	Former head of unit
Suzanne Andersson	Traffic safety co-ordinator
The Police	
Sten Byström, Rikspolisen	Worked with traffic safety and ATK
Rune Petterson	Former head of police in Umeå
Gunnar Andersson	Former researcher at VTI
Nils Göran Strömberg	Subject responsibility for traffic, policy development, Växjö University
Håkan Jaldung	Former head of police in Göteborg; previously on the National Police Board
Håkan Fuhrman	Politics lecturer and responsible for further education, policy development, Umeå University
Magnus Westergren	Police Academy
Per-Ove Nordquist	Police Academy
Chalmers University of Technology	
Per Lövsund	Professor, prefekt
Mats Svensson	Professor

Name	Title/area of responsibility
Lund University, Department of Technology and Society	
Christer Hydèn	Professor
Lisa Jonson,	Doctoral student
Åsa Svensson	University lecturer
Andras Varhelyi	Professor
Statens väg-och transportforskningsinstitut (The Swedish National Road and Transport Research Institute)	
Pontus Matstoms	Head of Department
Hans Erik Petterson	Professor at Chalmers, research and marketing director
Hans Thulin	Research leader
Thomas Turbell	Senior engineer
Uppsala University, Department of Psychology	
Mats Haglund	Researcher
Henriette Wahlin Warner	Doctoral student
Lars Åberg	Professor (20 % Uppsala University, 80 % Dalarna Polytechnic)
The national Society for Road Safety	
Gunnar Carlson	Former head of traffic safety NTF and head of research VTI
Nils Petter Gregersen	Professor, former researcher at VTI, now head of traffic safety NTF
Industry	
Hans Norin	Volvo Car Corporation. Professor of safety research Chalmers
Yngve Håland	Autoliv. Associate professor Chalmers
Björn Lundell	Expert in internal safety Volvo Car Corporation
Arne Wäbo	Group leader ergonometry, GM (Saab in Trollhättan)
Folksam	
Maria Krafft	Head, Traffic and society
Anders Kullgren	Head, Traffic safety research
The EU-system	
Jean-Paul Repussard	Policy officer in the Directorate General for Energy and Transport (DGTREN)
Antonio Avenoso	Deputy director in the European Transport Safety Council (ETSC)
Others	
Anders Englund	Former head of research VTI. Associate professor emeritus. Uppsala University, NTF etc.
Ernst Nilsson	OECD, formerly TOS-AB

Dialogue partners and contacts at VINNOVA and Programrådet för fordonsforskning (PFF) (Programme Council for Vehicle Research)

Title	Area of responsibility
Torbjörn Winqvist	Responsible for evaluation
Joakim Appelquist	Analyst
Gunnar Lindstedt	Programme leader, PFF
Hans Mohlin	Development director
Carl Naumburg	Programme leader
Ove Pettersson	Analyst/advisor
Joakim Tiséus	Head of transport unit

APPENDIX 2:
Tables and overviews

APPENDIX 2 :
Tables and overview

Table V.1: Swedish participation in traffic safety projects under the EU's 6th. Framework Programme.

Source: EUs website

Thematic area/ Project name	Coordinator	Number of partners	Swedish partners/ Total proportion
Road Safety Observatory			**2/6**
ECBOS	Technische Universität Graz	6	-
ETAC	International Road Transport Union	8	-
MAIDS	Association des Constructeurs Européens de Motocycle	8	-
PENDANT	Loughborough University	14	Chalmers
SAFETYNET	Loughborough University	20	Chalmers
SAU	INTRAS	5	-
Vehicle Safety			**12/22**
ADVISORS	SVOW	15	VTI
ALCOLOCK	Belgian Institute for Road Safety	4	-
APROSYS	TNO Automotive	46	Chalmers
APSN	TNO Automotive	50+	Chalmers
AUTOFORE	CITA	5	-
CHILD	Renault	13	Chalmers
CITA 1	CITA	10	Bilprovingen
CLEANER DRIVE	Energy Saving Trust	16	TFB
CONSPICUITY	TÜV Rheinland	2	-
COST 327	TRL	13	Göteborgs Univ.
DRL	TNO Automotive	2	-
FID	TNO Automotive	5	-
HASTE	ITS Leeds	8	Volvo VTI
IDELSY	RWTÜV Fahrzeug GmbH	0	-
MIRRORS	Jacobs	0	-
NPACS	Der Österreichische Automobil-, Motorrad- und Touring Club	12	-
PROSPER	The Swedish Road Administration	13	Lund Univ, Trasek, SWECO VBB VIAK
SARAC II	Comité Européen des Assurances	17	Folksam
SPEEDALERT	Intelligent Transport Systems and Services – Europe	15	The Swedish Road Administration

Thematic area/ Project name	Coordinator	Number of partners	Swedish partners/ Total proportion
VC-COMPAT	TRL	12	Chalmers Scania Volvo
VERONICA	Siemens VDO	34	-
VIRTUAL	Scuola Superiore Sant'Anna	7	-
Behavior			**31/16**
CAST	Belgian institute for road safety	18	VTI
EURO-BOB 2004-2005	Belgian institute for road safety	3	-
EURO-RS WEB	Belgian institute for road safety	7	-
GADGET	Kuratorium für Verkehrssicherheit	0	-
GLARE	The Netherlands Ophthalmic Research Institute	5	-
IMMORTAL	Kuratorium für Verkehrssicherheit	9	-
MEDRIL	International commission for driver testing	4	-
NESA	Fondation Tanguy Moreau de Melen Responsible Young Drivers	2	-
PROMISING	SVOW	13	The Swedish Road Admini-stration
QUAVADIS	Elderly and Disabled Project Con-sultancy	7	-
RED CROSS 2004-2005 RESPER	Red Cross/EU Office	0	-
ROSE-25	European Commission – DG TREN	0	-
ROSITA 2	Ghent University	10	-
TRAINER	Belgian institute for road safety	12	VTI
YOUTH ON THE ROAD	PAU	0	-
Infrastructure			**10/15**
EURORAP	The AA	26	Motormännens RF The Swedish Road Admini-stration
EURORAP II	The AA	18	Motormännens RF The Swedish Road Admini-stration
EUROTAP	ADAC	15	-

Thematic area/ Project name	Coordinator	Number of partners	Swedish partners/ Total proportion
FAIR	Deutsches Zentrum für Luft und Raumheit	7	-
FORMAT	Dienst Weg- en Waterbouwkunde	16	VTI
IASP	Provincia Regionale di Catania	0	-
IMPROVER	BAST	14	Chalmers VTI
RANKERS	Centre for Automotive Research and Development	16	Chalmers The Swedish Road Admini-stration
RIP-CORD	BAST	16	-
RISER	Chalmers	9	-
SAFE-T	TNO Automotive	22	Fire Safety Design
SAMARIS	Danish Road Directorate	22	VTI
IN-SAFETY	Centre for Research and Technol-ogy	28	VTI
SENSOR	ETRA	7	-
SILVIA	Belgian Road Research Centre	15	Skanska AB VTI
Enforcement			**4/5**
ESCAPE	VTT	12	VTI
IMPACT ECONOMIC	ICF Consulting	1	-
PEPPER	VTT	17	VTI
SARTRE	INRETS/VTT	20	The Swedish Road Admini-stration
TRAFFIC RULES STUDY	INRETS/VTT	21	The Swedish Road Admini-stration

Table V.2: VTI and the University of Lund's contribution to the international dissemination of results in developing countries and in former Eastern Europe respectively. Number of participants in brackets.

VTI		
Educational input	**Period**	**Target group (no of participants)**
Course on *Traffic Safety Management*	1985-2002	Developing countries
Course on *Traffic Safety Management*	1995-1998	Eastern Europe
Course on *Freight Management*	1995-2002	Developing countries/ Eastern Europe
Course on *Environment and Public Transport Management*	1995-2002	Developing countries/ Eastern Europe
Courses and seminars on traffic safety commissioned by the developing country or regions	Ca. 90 - 2002	Incl. Panama, Argentina, Chile, Brazil (several) Costa Rica, Uruguay, South Africa (several) Botswana, Uganda, Ghana and Russia (several).
Distance learning in traffic safety	1999-2002	South Africa, Botswana, Namibia, Malawi and Zimbabwe.
Conferences	**Period**	**Target group/ participants**
13 conferences on traffic safety, 250-300 delegates per conference.	1988-	International
International Forum on Road Safety Research, regional conferences.		Incl. Thailand, Brazil, South Africa, Bahrain.
National traffic safety conferences		Incl. Russia, Estonia, Lithuania, Poland, Latvia.
University of Lund, "Traffic and Roads " unit		
Longer courses	**Period/**	**Client (no of participants)**
Training Programme in Road Traffic Safety	2004-	SIDA
Free-standing international 1 semester course on *Traffic Safety Science*	2004-	
Short courses (1-2 weeks)		
Bolivia	1992	SIDA (10)
Brazil	1992	SIDA (15)
Jamaica	1993, 2000	Sweroad/SIDA (15)
Thailand	1996, 99	Sweroad/World Bank (25)
Uruguay	1997	VTI Utv/IADB (25)
Panama	1995	VTI Utv/IADB (25)
Brazil	1996-97	VTI Utv/IADB (30)
Botswana	Ca 1999	VTI Utv (35)
Chile	1999	Uni. of Concepcion (20)
Chile	1998	Comisión Nacional de Seguridad de Tránsito (35)

VTI		
Sri Lanka	2002	SIDA (15)
Turkey	1999	Sweroad (20)
Uganda	1999	VTI Utv/IADB (25)
Hungary	1993, 94	KTI, Hungary (20)
Tanzania	1996	Local universities (15)
Costa Rica	1999	Sweroad (48)
Collaboration		
Course on *Urban transport*	2005-	SIDA
Science and Management of Road Safety	2004-05	University of Rey Juan Carlos n Madrid.
Traffic Safety Management	1985-02	VTI

Table V.3: Data modules as a basis for measuring values of R&D investments and model frameworks for analysing the total added value in user-steered projects.

Source: The Norwegian Research Council (Provis is the Norwegian Research Councils selection system)

Data modules		Comments
1	Project evaluation and selection (Provis*) – systematic evaluation of all applications for user-steered programmes	During project selection, a number of indicators that are relevant/ important for use of R&D funding in the programmes are evaluated. The combined score in Provis forms an important basis for decisions about project funding.
2	The company's expectations at start -up – sample surveys at project start up,, telephone interviews, Møreforsking Molde (MFM)	At start-up, the project owners (the Company's) expectations of results are studied and described using different indicators to measure additionality etc,
3	Achieving results at the end of the project – sample surveys, telephone interviews (MFM)	When a project is completed for the Research Council, the project owner is interviewed again and questioned about the results that have been achieved and further expectations for the project.
4	Reporting results –obligatory reporting by project owners to the Research Council, "tellekanter"	During and at the end of the project, all project owners report measurable results (articles in international refereed journals, PhDs, the number of new establishments, newly developed products, patents etc) that result from the projects. These provide quantitative measures of what has been achieved.
5	Long term measurement of results – sample surveys, telephone interviews (MFM)	4 years after completion, the project owners are interviewed again to see what the long-term results have been.

Level I N/K-The analysis		Comments
A	The project’s private financial profit in the main project and in spin-offs	Long-term result measurements provide information about financial results that are used as a basis for a quantitative economic analysis (calculating net current value).
B	Indicators that can supplement the private financial analysis	A set of indicators is drawn up from the different data modules that are supplementary to the analysis of the private financial returns. This show which other results from the R&D activity are significant for the companies and a quantitative goal is set for what these mean in relation to the company's financial targets.
C	Scope (degree) of external effects	A set of indicators is drawn up which can indicate the degree of external effects, i.e. different effects that cannot be measured as results by project owners, bur which have different positive financial implications for other companies or R&D institutions/
D	Consumer surplus	A set of indicators is drawn up for socio-economic benefits that can occur in the form of a consumer surplus as the result of new or improved products. In the subject literature, the customer surplus means the extra benefit that the use of new goods achieves over and above what people pay for the goods, An example of a customer surplus can be that the benefits of access to mobile telephones far exceed the costs to users.
E	Additionality Significance of project funding for realisation of the project.	Indicators for additionality can be obtained from the data modules.
F	Ability of the research council to select the best projects,	Is there some connection between the selection criteria (ex ante) and the results achieved in the project in the long term? If we do not find any significant connections, this may mean that it is not possible to pick the "winner” in an applicant population. This means that case management could be replaced by a pure lottery. If there are a high number of projects in Provis with relatively good evaluations that are turned down, the selection model could form an important basis for evaluating whether enough funding is being granted to these types of user-steered programmes.

Table V.4: Measures in the Norwegian Traffic Safety Handbook (Elvik et al 1997) where Swedish researchers are responsible for more than 25 % of the surveys that make up the meta-analyses. There are 124 measures in total in the Traffic Safety Handbook.

Staggered junctions (cross-roads to two T-junctions)
Reconstruction
Rehabilitation and resurfacing of roads
Erecting game barriers
Winter maintenance of roads
Pedestrian streets
Stop signs at junctions
Improving vehicle headlights
Under-run guardrails on trucks
Safety equipment on trucks and heavy vehicles
Fire safety standards
Hazardous goods regulations
Motivation and incentive systems in the work place
Education of pre-school children (0-6 years) NB see Englund.

Table V.5:Road design and road equipment in the Traffic Safety Handbook. Proportion of Swedish references and potential accident reducing effects of the measure (here we use B/C-ratio = cost-benefit fraction).Measures with B/C > 1.0 are marked with a light blue background in the table. Text in bold indicates where Sweden has contributed to a measure

Measure	No of Swedish refs	Total number	B/C-ratio
Tracks for Walking and Cycling	19	32	unknown
Motorways	0		0,15-0,35
Bypasses	**20**	**10**	**1.1**
Arterial roads in and around cities	0		1.1- 3.0
Channelisation of junctions	**19**	**26**	**1.1 - 2.67**
Roundabouts	**15**	**33**	**2.0 - 2.5**
Redesigning junctions	17	6	0.1
Staggered junctions (reconfiguring crossroads to two T-junctions)	33	9	0.66
Interchanges	11	9	0.66
Black spot treatment	**3**	**38**	**1.9**
Cross-section improvements	16	63	
Roadside safety treatment	0		
Improving alignment and sight distances	**22**	**9**	**3.25**
Reconstruction, Rehabilitation and Resurfacing of roads	45	11	0.5
Guardrails and crash cushions	**11**	**?**	**2**
Erecting game barriers	47	7	0.1
Horizontal curve treatments	8	12	0.25 - 12.6
Road lighting	**8**	**63**	**0.5-1.9**
Improving tunnel safety	0		1.1
Rest stops and service areas	0		unknown

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Head of Research: Rune Elvik

APPENDIX 3
Case study: Speed-reducing measures in towns and cities, including roundabouts

Contents

1 Introduction

The Institute of Transport Economics and Møreforskning Molde have been employed by VINNOVA to carry out an analysis of the effects of Swedish traffic safety research for industry and for society. The study covers five different case studies, chosen because they represent different types of research perspectives, different traffic safety measures and work with defined subject areas in the period 1970-2004. This approach means that we will not present a complete overview of all Swedish traffic safety research in the actual case area.

In this document, for example, we present a case study and effects analysis for speed-reducing measures in towns and cities. Here the focus is on the research that was carried out by Lund University, particularly the development of roundabouts as a speed-reducing measure in towns and cities and the tests carried out in Växjö. This means for example that we will not be looking at earlier work carried out at Chalmers (sektion för stadsbyggnad).

This representation is also intended to provide a model for the socio economic calculations in the other case studies. The point here is to show the process of the analysis and the types of information that that are required.

2 A proposal for action and a model for effect calculations

Each case study has been set out according to the pattern devised for the study of whiplash research (Sandberg Eriksen et al 2004). This means that for each case study, an analysis will be carried out at the following levels:

1 Previous studies that have evaluated effects on traffic safety of measures developed as part of the research projects have been evaluated and summarised. In this way, an estimate is obtained of the percentage effects on accidents or injuries.
2 Contact is made with users of the research results in order to chart the scope of the measures, for example the number of roundabouts that have been built, the justification for building these (the role that research has played) and so forth.

3 By combining estimates of effects for evaluation studies with Swedish accident statistics and information from the users about their use of the measures, estimates of the total effects of the measure concerned can be calculated for accidents and injuries in Sweden.

4 The number of accidents and injuries that are prevented as the result of a research-based measure are converted to a benefit to society by using available evaluations for traffic safety in Sweden (a number of evaluation studies and official figures are available).

5 The costs of developing and implementing a research-based measure are identified. The costs of the research cannot be fully estimated on the basis of VINNOVA's project database alone. The costs of the measures must also be based on other sources.

6 Costs and benefits are shown to demonstrate the socio-economic profitability of the measures. Possible business-economic benefits are also discussed.

3 Level 1: What has been the Swedish traffic safety research contribution?

According to the internet-based Wikipedia encyclopaedia, the world's first roundabout was constructed in 1904. The development of so-called modern roundabouts, where traffic on the approach roads must give way to traffic on the roundabout, first started in around 1980, after favourable results were achieved with this type of roundabout in Great Britain.

A meta- analysis of roundabouts' effects on accidents, based on studies carried out outside the USA (Elvik 2003) showed that roundabouts reduced the number of fatal accidents by 50-60 % and the total number of injury accident by 20-40 %. The meta-analysis built on 28 studies. Of these, 4 were Swedish. However, the Swedish studies represented a total of 36 % of the total statistical weight that was added to the studies in the meta-analysis.

The Transport Research Board, together with a number of other clients, funded a major project at Lund University on how the traffic safety in a Swedish municipality could be improved. Växjö municipality was chosen as an example. On the basis of an accident analysis, it was concluded that high speeds in the municipality's city centre were an important contributory factor to accidents. In order to reduce speeds, 21 intersections in the city were converted to roundabouts and 4 intersections were given so-called four-way Give Way status, i.e. where Give Way signs were put up on all the approach roads. The main report from the project (Hydén, Odelid and Várhelyi 1995) showed that speeds went down significantly at intersections that had been converted to roundabouts. The number of conflict situations and traffic accidents were also significantly reduced. The most important results of the study are presented in an article in Accident Analysis and Prevention (Hydén and Várhelyi 2000).

The study in Växjö attracted great attention from the mass media in Sweden. It may have contributed to the study becoming well known, and also to the safety benefits that can result from converting intersections to roundabouts becoming well known. All in all it can be said that Swedish traffic safety research has made a significant contribution to knowledge about the effects of roundabouts. This knowledge has been disseminated through scientific publications, research reports, guidelines from SKL (The Swedish Association Of Local Authorities And Regions), courses and seminars, as well as notices in the mass media.

4 Level 2: Using the knowledge in Sweden – speed-reducing measures in towns and cities

According to a knowledge overview produced by VTI (Vadeby and Brüde 2006), in 198o there were about 150 roundabouts in Sweden. This figure had increased to around 1500 by 2006. There have clearly been significant numbers of conversions of intersections to roundabouts in Sweden in the period 1980-2006.

Inspired by the Växjö experiment, several cities in Sweden have focused on speed-reducing measures in order to improve traffic safety. One of the most successful programmes has been carried out in Göteborg (Johansson 2005). Over 2,200 speed-reducing measures have been introduced, including 621 raised footpaths, 62 bust stops with road narrowing, 315 speed bumps, 145 road narrowings, 138 roundabouts and 38 raised intersections. In the period from 1985-1989 up to 2003 it has been calculated that these measures have contributed to a decrease of 47 % in the numbers killed or seriously injured in Göteborg.

5 Level 3: Macro effects of building roundabouts

SIKA (Swedish Institute for Transport and Communications Analysis) issues official statistics for road traffic accidents in Sweden. These statistics contain relatively detailed information about traffic accidents involving injuries. Information is given about whether accidents involving deaths or serious injuries occurring on roads or at intersections and the type of intersection where the accident happened. However this information is only available for the last few years. Therefore in order to get information going back to 1980, for example, it is necessary to search through years of statistics or order a special print run.

Roundabouts are mostly built in towns and cities. We know that roundabouts reduce the numbers killed or seriously injured more than the number of minor injuries. If roundabouts have contributed in a measurable way to improving traffic safety in Sweden, we could therefore expect that from around 1975 (when there were few roundabouts) up to the present day there would have been a greater decrease in the numbers killed or seriously injured in towns than in more sparsely populated areas. We will return to the fact that this decrease is also linked to other measures and strategies.

Table 1 shows changes in the numbers injured or killed from the period 1974-76 (annual average) to the period 2002-04 (annual average)for towns and sparsely populated areas in Sweden.

Table 1: Changes in the numbers killed or injured in road traffic accidents in Sweden from 1974-76 to 2002-04 according to housing density.

Period	Degree of injury	Densely populated	Sparsely populated	Sweden as a whole
1974-76	Killed	404	775	1179
	Seriously injured	3317	3479	6796
	Minor injuries	7972	6416	14388
2002-04	Killed	135	388	523
	Seriously injured	1941	2485	4426
	Minor injuries	11591	10127	21718
Change in percentage	Killed	-67 %	-50 %	-56 %
	Seriously injured	-41 %	-29 %	-35 %
	Minor injuries	+45 %	+58 %	+51 %
Net change in Towns	Killed	-34 %		
	Seriously injured	-18 %		
	Minor injuries	-8 %		

Source: SIKA 2005.

There has been a greater decrease in the numbers killed or seriously injured in towns than outside towns. If it is assumed that the decrease in deaths or injuries in sparsely populated areas can only be explained to a small extent by the building of roundabouts, the changes in sparsely populated areas can be used as a control group to calculate the net changes in towns that can be explained by factors other than those that also affect sparsely populated areas. The result is a net decrease of 34 % in the numbers killed, 18 % in the numbers seriously injured and 8 % in the number of minor injuries.

These overview figures do not in themselves explain the fact that development of traffic safety has been better in towns than in sparsely populated areas in Sweden. Building roundabouts can undoubtedly be one of the factors, but other traffic safety measures have also been introduced. This is bound up with major methodological problems in identifying the exact size of the contribution that a specific traffic safety measure has given to the long-term development in the numbers killed or injured. More detailed analyses of this development could possibly be done by studying the number of accidents at intersections. However, special print runs would be required from the accident statistics.

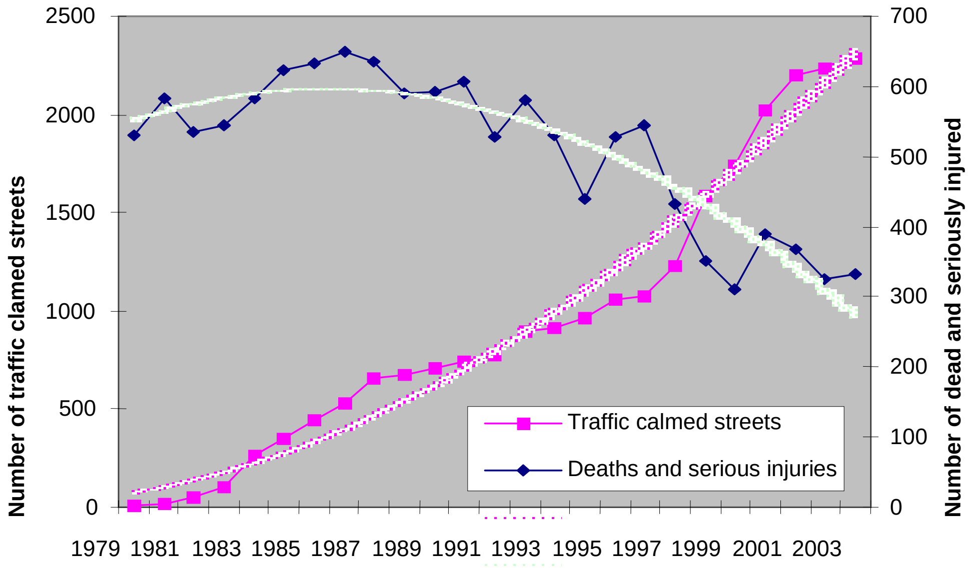
Nilsson et al (2002), in an analysis of the traffic safety development in Sweden from 1990 to 2001 estimated that building of roundabouts had reduced the numbers killed by 20. Between 1990 and 2000 some 500 roundabouts were built in Sweden, i.e. about 1/3 of the total figure for 2006. A simple expansion of the figures therefore indicates that roundabouts may have reduced the numbers killed in traffic in Sweden by 60 people.

The decrease in the annual numbers killed in towns in Sweden from 1974-76 to 2002-04 was 269 people. The net decrease, controlled for the development in sparsely populated areas can be estimated at 137 people,. The figures above indicate that building roundabouts can explain about half the net decrease in the numbers killed in towns. Seen in connection with the calculations of what other explanatory factors may have meant, this appears somewhat high (Nilsson et al 2002). In the further analysis, the starting point is that building roundabouts in Sweden has reduced the numbers killed by 40 people. Reductions of 20 or 60 respectively are used in the sensitivity analyses.

If it is assumed that building roundabouts has given the same proportional contribution to the net reduction in the numbers seriously injured and the number of minor injuries in towns in Sweden as its contribution to the net reduction in the numbers killed (40/137 = 29 %), the net contribution is estimated at about 170 fewer seriously injured and about 180 fewer minor injuries (than would otherwise have been the case: the actual number of minor injuries has increased).

Figure 1 shows the development in the number of speed-reducing measures and the numbers killed or seriously injured in Göteborg.

Figure 1: Development in the number of speed-reducing measures and the numbers killed or seriously injured in Göteborg 1979-2003. Source: SKL 2005



6 Level 4: Economic evaluation of the benefit of speed-reducing measures

SIKA has produced official economic evaluations of effects of transport measures for use in cost-benefit analyses. Calculated in 2001-prices, the benefit to society of preventing one death in traffic was valued at SEK 17.511.000, the benefit of preventing a serious injury was valued at SEK 3.124.000 and the benefit of preventing a minor injury was valued at SEK 175.000.

Under some circumstances, roundabouts can also influence traffic development (accessibility) and exhaust levels. The effect on traffic development and exhaust levels depends first and foremost on the amount of traffic at the roundabout, the distribution of incoming vehicles on the approach roads and previous forms of traffic regulation at the intersection (Give Way, Stop or signals). We think it is less important to include these effects in an overview analysis. Including them would require detailed calculations linked to speed, quantity of traffic etc. It is uncertain how representative these calculation conditions would be.

In Växjö major time benefits were achieved at a former signal-regulated intersection, but there is a net loss of time at other intersections. It is not known how many of the 1500 roundabouts which are found in Sweden were previously signal regulated and how many had other forms of regulation.

The effects on time usage are therefore difficult to calculate. However it seems clear that traffic noise has been reduced at the majority of intersections.

7 Level 5: Research and development costs

Funding from The Transport Research Board for the project ”Trafiksäkerhet i en Swedish municipality” (the Växjö-project), and follow-up, was around SEK 2.3 million. However, this project also received funding from other clients. Research into the design and effects of roundabouts has also been carried out at institutions in Sweden other than Lund University, primarily VTI.

A number of other projects funded by VINNOVA, PFF (Programme Council for Vehicle Research) and its predecessors have also had safety in towns and cities as a theme. This applies to everything from methodological and theoretical studies, to understand the interaction in traffic, to the study of special measures such as roundabouts. The costs of research and development linked to roundabouts can be estimated at around SEK 10-20 million. This corresponds approximately to the benefit of one saved human life, which was calculated to be SEK 17.5 million in 2001.

The representatives for Göteborg’s traffic administration whom we have interviewed stated that research based measures are a significant explanation for the positive development in Göteborg. Traffic safety work in Göteborg has been research-based *directly* through the projects that people have participated in themselves in various ways, and *indirectly* in that they have always been based on research results through implementing and evaluating measures, They feel that the reason why Stockholm has experienced an increase in injury accidents is because the focus has been on the wrong measure (politically-steered?)) The focus was on 30 kilometre speed limits largely without any physical measures. Göteborg municipality has supported research both by contributing to programmes (part funding) or by issuing statements of support. The work has been carried out in close contact with Lund University. Other collaborating partners have included Vägverket (Swedish Road Administration). Otherwise the research institutions have not been particularly adept at marketing themselves to the municipalities. Here there is potential.

8 Level 6: Socio-economic analyses of speed- reducing measures

Previous analyses of Swedish traffic safety policies (Elvik and Amundsen 2000) indicate that building roundabouts at four-way intersections is socio-economically profitable if the amount of traffic is more than 5,000 vehicles per day. It was assumed that converting a four-way intersection into a roundabout would cost on average SEK 2 million (Brüde and Larsson (1985) give the costs of building a roundabout as SEK 1 million (ca 1980 price levels). Adjusting this figure to today's prices gives a cost of about SEK 2.8 million for 2006. In Norway the costs of building a roundabout is at present around SEK 4-5 million.

The roundabouts in Sweden have been built over a number of years. The historic costs of building the roundabouts are lower than what it would cost to build a corresponding number of new roundabouts today. In order to make the analysis as simple as possible, today's cost figures are used in the socio economic analysis.

It is assumed that 1500 roundabouts have been built in Sweden. Assuming that each roundabout cost SEK 3 million, based on today's prices, the total investment in roundabouts made by Swedish society is calculated to be SEK 4.5 billion SEK (1500 x 3 = 4500 mill SEK).

The investments have come from public budgets. SIKA recommends that in socio-economic analyses of public investments a tax cost factor should be added to the budget cost. This factor is currently 1.53. Multiplying the budget cost by this factor gives a socio economic cost of SEK 6.89 billion.

Above, the benefit is estimated at 40 fewer killed, 170 fewer seriously injured and 180 fewer minor injuries than would otherwise have been the case. If the benefit for just one year is calculated, then:

For killed:	17.511.000 x 40	=	700 mill SEK
For Seriously injured:	3.124.000 x 170	=	530 mill SEK
For Minor injuries:	175.000 x 180	=	30 mill SEK

The total benefit for one year is thus SEK 1.26 billion.

A roundabout is a permanent development of a road that will give benefits for a number of years. In a socio economic analysis, the future benefit must also be included, not just the benefit for the first year. One problem in this context is that some of today's roundabouts in Sweden are old and have probably already done their bit in terms of benefit. However we have decided to ignore this complication and use the same argument in a standard socio economic analysis. The question then becomes: If today we build 1500 roundabouts that reduce the numbers killed by 40, the numbers seriously injured by 170 and the number of minor injuries by 180, what is the present value of the benefit of these investments?

SIKA recommends that a 20-year time perspective be used for traffic safety measures and a rate of interest for accounting purposes of 4 % annually. The present value of the benefit calculated above is then SEK 17.1 billion. The benefit clearly exceeds the investment.

If it is estimated that the effects are only half as big as stated here, the benefit is then SEK 8,56 billion, which is still more than the costs.

A similar analysis has been carried out for Göteborg (Johansson 2005). Here the benefit was estimated to be 8 billion kroner. The building costs amounted to 170 million kroner. The increase in the annual maintenance costs is estimated to be 30 million kroner. Even correcting for tax costs, the benefit is significantly greater than the costs.

9 Speed reduction in the form of vehicle technology: ISA

Speed-reducing measures on the road network can be costly. This certainly applies to roundabouts. Smaller measures such as speed bumps are less expensive to install.

In recent years comprehensive tests have taken place in Sweden with vehicle technology designed to ensure better adherence to the speed limit, intelligent speed adaptation, also known as ISA. A number of reports have been published on these tests. A summary of the test trial in Lund was produced by Varhelyi et al (2004).

ISA comes in various forms. The form of technology which probably has the greatest effect on traffic safety is a compelling system that makes it impossible or very difficult to exceed the speed limit. This type of system can ensure approximately 100 % adherence to the speed limit. In this way, speed reductions can be achieved in towns without the use of physical measures.

A calculation for Norway shows that compulsory ISA could reduce the numbers killed in traffic by about 29 % (Elvik 2006). The benefit is greater than the costs. In order to gain more experience with this system, it is important that this research work continues.

10 Conclusions

The conclusions in this case study can be summarised as follows:

1. Swedish traffic safety research has made important contributions to the development of knowledge about roundabouts. Elements from these contributions are published in recognised scientific publications.
2. A large number of roundabouts have been built in Sweden during the last 25 years. Knowledge that roundabouts are an effective safety measure is highly likely to be a contributory factor to roundabouts being built.
3. There has been a greater decrease in the numbers killed and seriously injured in traffic in towns in Sweden that outside towns. Building roundabouts is one measure that has contributed to this, but it is very difficult to quantify the exact contribution made by roundabouts.
4. The research has also covered a number of measures for increased safety in towns that have contributed to this favourable development.
5. Using careful estimate of the benefit of roundabouts as a basis, the benefit is greater than the investments that have been put into building roundabouts. Roundabouts contribute to the numbers killed in traffic in Sweden probably being 20-60 lower annually than they otherwise would have been. The benefit exceeds the costs even when the lowest number for the decrease is used as a basis.

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APPENDIX 4

APPENDIX 4
Case study: Developing and standardising rearward-facing child seats in cars

Contents

1 Children are exposed in traffic

Traffic accidents account for a large proportion of childhood accidents with fatal outcomes. OECD (2004) states that the proportion is 40 % for the OECD-countries. However, over time the accident risk for children in traffic and in cars has become steadily lower, not least in Sweden (Brüde 2005). Swedish traffic safety research has undoubtedly contributed to this, through the development of knowledge and different measures, in relation to safety in the local environment, on school roads ad in cars. Here we will focus on restraints for small children in cars (CRS – Child Restraint Systems). We will look in particular at *rearward facing child car seats* designed for 0-4 year olds and at mechanisms for encouraging the use of such seats, a field where Sweden and Swedish research have been at the forefront. Sweden has also occupied a central role in developing a number of other important safety measures for children such as different seat cushions for sue with safety belts for larger children. We will not look at these in this study.

Research related to this theme has received public funding right from the start:

- Research Council funding, firstly from Statens Trafiksäkerhetsråd (The National Traffic Safety Council) and thereafter from VINNOVA, PFF and their predecessors
- Basis funding for VTI and Chalmers
- Funding from different traffic authorities, primarily Vägverk but also Trafiksäkerhetsverk (The National Traffic Safety Administration) and Skyltfonden (the Registration Plate Trust Fund)

In addition, the car industry and the insurance industry have also contributed both with funding and with their own research. A number of organisations, for example NTF (Nationalföreningen för Trafiksäkerhetens Främjande) have provided funding. Current research institutions that have specifically worked on children in cars are VTI, Chalmers and Volvos research department. VTI is also an accredited authority for testing child restraint equipment.

In this example we want to study mechanisms for achieving actual changes /results on the basis of research-based knowledge. Knowledge alone is not usually enough: it requires interaction with authorities, organisations and industry; see the effect model shown in chapter 7. Standardising and regulations/ guidelines can be important mechanisms for ensuring practical use of research knowledge. In addition, when this involves - as in this example- developing projects of significance for safety, there is probably a need for a close connection with industry, given that expertise in utilising knowledge for commercial purposes is usually to be found here

In the following we will first describe different restraint methods and their effects in order to provide a background. Thereafter the history of research into rearward-facing child car seats will be described and how this innovation was financed by different sources of funding (Input additionality) and was followed up in different Swedish subject environments (Behavioural additionality). With regard to the end effects (Output additionality) we look at effects for society both for Sweden and internationally, at the commercial opportunities and at the mechanisms that can provide such effects.

2 Different restraint methods and effects

In the event of overturning, collision or sudden braking, children in cars who are not fastened in or restrained in other ways have a high risk of being injured by being thrown against the interior of the car or being thrown out though windows or doors. A child who uses a child seat/ seat belt or other restraining equipment will be held in their seat in the event of an accident and the speed will reduce along with that of the car. The equipment must be able to transfer changes in the car's movement energy so that the force that affects the body is spread over a longer period of time, a greater distance and over larger areas of the child's body than would be the case without restraints.

Today Swedish legislation (Trafikförordningen (1998:1276) and The Swedish Road Administrations directives (VVFS 1993:5) require that everyone travelling by car must use a seat belt. Furthermore, children under the age of 6 must

> *"use a special protection system, baby seat, child car seat or belt seat/ cushion."*

VVFS 1993:5 also prescribes that

> *"The protection system must be suitable for the user and must be used on the correct seat"*

and that

> *"Rearward facing restraints should not be installed or used on seats equipped with crash cushions. This does not apply if the crash cushion is automatically disabled when a rearward facing restraint is used on the seat."*

The Law does not say anything about how a child seat should be located, but on the basis of the research considered in this chapter, we will recommend a rearward-facing location for children up to the age of 4.

We quote from VTI's homepage:

Why rearward-facing?

The difference between a crash test in a rearward-facing child seat and a forward-facing child seat at 50 kph and around 20G load is that the rearward-facing seat spreads the collision force over a large area. The whole package of back, neck and occiput are effectively slowed by the chair's back support.
In the forward-facing child seat, only the restraints slow the child's body; nothing helps slow the head apart from the neck which has to act like a rope to try and impede it. Naturally, the forces on the neck are great; in tests such as the one shown above, forces of around 50 kg can be measured at the neck when using a rearward-facing child seat and around 300–320 kg when using a forward-facing one.
Children are not miniature adults. In an adult human weighing 70–75 kg, the weight of the head is approx. 6% of the body weight or around 4.5-4.6 kg. For a child of just over a year old, the head is usually just over 25% of the body weight. Imagine how you would walk, cycle, drive a car etc. as an adult if you had the same proportions as a small child.

The legislation has recently been adjusted, see the Parliamentary proposition RP 207/2005rd with proposals for changes to the Road Traffic Act. From 1 January 2007 all children shorter than 135 cm must use specific restraint equipment (baby chair, child car seat, booster seat with belt/ cushion). Furthermore it states that children under the age of 3 may not travel in cars or lorries without special restraint equipment (with the exception of short journeys by taxi).

2.1 Restraint methods – meta-analyses of effects

The following choices are decisive for the degree of safety;

- Equipment that is suitable for the child's age, weight and length or not.
- Seating children in the front or the back
- Carry cot/ rearward facing car seat for very young children or not
- Forward or rearward facing child seat
- Seat belt only or seat belt combined with booster cushion

Table 2.1: Effects of restraining children in cars on thee child's risk of injury as a passenger in a car Percentage change in risk of injury

Degree of injury in the accident	Types of accident affected	Best estimate	Uncertainty in effect
Restraining new born babies using carry cot			
Injury (all degrees)	All accidents	-25	(-75; +120)
Restraining children aged 0-4 using child seats and seat belts			
Injury (all degrees)	All; forward facing seat	-55	(-76; -39)
Injury (all degrees)	All; rearward facing seat	-71	(-83; -51)
Injury (killed/seriously injured)	All; rearward facing seat	-90	(-96;-77)
Restraining children aged 0-4 with seat belts only			
Injury (all degrees)	All accidents	-32	(-35; -29)
Restraining children aged 5-9 with child seat and seat belt			
Injury (all degrees)	All accidents	-57	(-64; -50)
Restraining children aged 5-9 with seat belts only			
Injury (all degrees)	All accidents	-24	(-34; -14)
Restraining children aged 10-14 with seat belts only			
Injury (all degrees)	All accidents	-46	(-52; -39)
Restraining children aged 1-7 in child seats versus seat belts			
Injury (serious injury)	All accidents	-71	(-79;-59)

Source: TØI's Traffic Safety Handbook, net version with updates from 2007.

The Norwegian Traffic Safety Handbook's meta-analyses of the studies that were available in 2006 show that it is safest to place the child on the back seat. Children are safest if the correct restraining equipment is used for the child and especially the rearward facing child car seat, which is safer than the forward facing seat see table 2.1. Child seats are particularly effective against serious injuries. The figures in table 2.1 build on 19 effects studies carried out between 1977 – 2006, of which 7 are Swedish (Norin and Andersson 1978, Norin et al 1978, Norin et al 1980, Aldman et al 1987, Carlsson et al 1987, Tingvall 1987 and Jakobsson et al 2005).

2.2 Effects of different restraint systems – ISOFIX

In order for the equipment to have the best possible effect, it is vital that the equipment is used correctly, i.e. that the equipment is properly installed in the car and that the child is properly secured in its seat. Whether or not the equipment is integrated in the car, and the type of fastening system that is used for non-integral equipment are significant for how easy it is to use the equipment and hence for the effects. An analysis recently carried out by VTI and The Swedish Road Administration (2006) concludes that the installation is not the greatest safety problem when children are travelling by car. What counts is whether the restraint devices are used correctly or not. For example if the belt is wrongly fastened, this can lead to the child being injured. There are no separate effect figures for ISOFIX in relation to using seat belts compared with using other systems. Hence in the calculations we have focused on the method of restraint and not the fastening systems.

In the international discussion on what type of restraint equipment is best, the focus is also on what can hamper use. In Sweden it is maintained that rearward facing car seats can be difficult to install, especially on the back seat where some form of anchoring or support is needed (The Swedish Road Administration 2006). With ISOFIX which fixes the child seat to the car seat, it become easier to fix the rearward-facing seat. The system has two anchor points down in the seat (between the back and the cushion) that limit rotational movement of the child seat.

Three are also other fastening systems. LATCH which is used in the USA is a variant of ISOFIX and fully compatible with this system. UAS is another type with an additional fastening on the top of the car seat (top tether). This is used in Australia , which is one of the countries that prefers forward facing seats combined with a 6-point harness with double straps to secure the child in the seat. They say that this model leads to increased correct use and therefore has a lower risk than rearward-facing seats that may be incorrectly fastened. (Paine et al 2002). The fact that Australian child seats are always used on the back seat means that problems with inflating airbags are avoided.

3 History of the child car seat

It is difficult to define who first comes up with an idea. Sometimes, ideas are ”in the air” and occur in several places simultaneously, as is the case with traffic safety research. It may often be the case that new concepts are based on several building blocks that may all come from different environments, i.e. the ideal picture of cumulative research. Visibility in the international research community is not evenly spread. Here, resources to enable international participation, language and cultural spheres and closeness to industry and administration that can convert knowledge into practice all have a role to play.

We have tried to trace the origins and spread of knowledge for research into rearward-facing child car seats, and references to Swedish research by looking at the following publications and references within them: Original references to chapter 4.13 in the TS-handbook 1997, articles in Accident Analysis and Prevention from 1969 to 2006, Journal of Safety Research from 1969-2006, Injury Prevention from 1995-2006, VTI’s literature study on Child safety in cars (Anund et al 2003) and OECD’s report on Keeping Children Safe in Traffic from 2004. We have also looked at Englund's

(2000 and 2005) descriptions of Swedish traffic safety research history and obtained input from several of the people we have interviewed in connection with the project or who have commented on the draft case description.

Based on this, we can confirm that the Swedish authorities, Swedish research and the Swedish car industry were well ahead in meeting the need for special safety measures for children. It is reasonable to assume that *Samarbets-komiteen mot barnolyckor* that was set up as early as 1956 played an important role and created a pattern for close co-operation between different players. The Swedish contribution apples to a number of measures for restraining children in cars. In this project, we will focus on the role of Swedish research in developing rearward-facing child car seats and also look at the development of the ISOFIX standardising system

3.1 Aldman's innovation – a new way of thinking

It was the Swedish doctor Bertil Aldman who ”discovered” the rearward-facing child car seat. This occurred early in the 1960s (Isaksson- Hellman et al 1997, Carlsson et al 1989). The first reference we have found for the subject of Child Restraints is from the early 1960s and written by Aldman (1963 and 1964). At this time, Aldman held one of the Transport Research Council's research posts and led the council's medical research laboratory. His doctoral thesis on ”Biodynamic studies on Impact Protection” (Aldman 1962) formed the starting point for his innovation in the area of child restraints.

According to Carlsson et al (1989) Aldman designed the rearward-facing child seat on the basis of principles from space research combined with knowledge of children's anatomy. The purpose of the rearward-facing seat is to spread the forces that arise in a frontal collision over as large an area of the child's body as possible and to provide support for the spine. This is important for small children since their bodies have a disproportionately large head and a weak neck.

The seat appears to have been one of the first safety installations for children and Aldman's innovation formed the basis for completely new thinking on the safety of children in cars, and even about children and traffic in general. We think that from this time onwards children were no longer seen as small adults but as a separate group with their own characteristics and physical and psychological abilities to deal with traffic or for being affected by injuries in cars. With regard to children in traffic, Stina Sandel's (1969) work on children's inability to understand traffic was a clear (psychological) parallel to Aldman's indication that children's' anatomy is different to that of adults, and therefore they are particularly exposed to certain injuries in car accidents. [1]

A further illustration of how groundbreaking Aldman's research was can be found in the Swedish Barnmiljøutredningen from 1975. In dealing with childhood accidents, the focus is on children in traffic. Restraining children in cars is only mentioned in one short paragraph and with Aldman as the only reference:

> *"In this context is should be noted that children who are passengers in cars should be the object of specific studies (Aldman 1966). Special seat belts and safety seats have been tested band are recommended for the prevention of traffic accidents and the type that cause major injuries." (SOU 1975:32)*

Volvo's overview of milestones in the development of safer cars (www.Volvo.se), also shows that Aldman's child car seat was a starting point. Volvo created a prototype as early as 1966 and produced child car seats from 1972. According to Carlson et al (1989) the seat was available on the Swedish market towards the end of the 1960s. Hylte and Klippan produced child car seats from 1968 and from 1972 Volvo had their own rearward-facing child car seat. Volvo and Chalmers (Aldman) had a dialogue on car seats in 1972 and Volvo may have paid for the crash tests.

Authorities and organisations quickly came up with recommendations, legislation and other measures. Aldman's innovation formed the basis for comprehensive research into linked themes and for collaboration between research and the car/equipment industry and hence for a whole series of safety products for children. Aldman's child seat also provoked international interest and created a discussion on different solutions that is still going on today.

Australian researchers and authorities were also well ahead with the work to increase children's safety in cars, but they appear to have started somewhat later than the Swedes. Paine et al (2002) state that the Australian research began at the end of the 1960s and that an Australian design directive was presented in 1976. There was also early collaboration between Swedish and Australian researchers.

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[1] Sandels documented in an insightful way that children right up to the age of 10 do not understand things in the same way as adults do and do not understand relative conditions (you should not stand on the edge of the pavement, even if you have been asked to do so, to see if the road is clear, if there is a car in the way). You need to go to the edge of the car to see). In addition, children are small, and do not have an overview, do not have fully developed side vision etc.

3.2 The main innovative concept came before 1971

Our study focuses on Swedish public funding for research after 1971, i.e. the period when TFD, TFB, KFB, PFF and VINNOVA were responsible for parts of the publicly funded traffic safety research. Since the rearward-facing child seat was developed by Bertil Aldman early in the 1960s, wee need to go a little further back in time than 1971.

The National Traffic Safety Council's medical research laboratory worked on tests and crash tests regarding the fixing characteristics of safety belts and biological tolerance for retardation forces in collisions. The council also had a child psychology laboratory and three research services outside the council's own work. The medical laboratory used half of the council's funding for its own research. This research was also funded by Volvo where a prototype seat was tested in 1964 and produced in 1972. The Folksam insurance company was another source of funding (Chalmers self-evaluation 2006).

The council was set up in 1949 in order to improve the knowledge base for transport policy and to ensure practical application of the knowledge. Among the 16 members of the council were key players in public administration (the Head of Väg- och vattenbyggnadsstyrelsen, the Chief of the National Police) and society generally (NTFs director). The council's researchers created an interdisciplinary group (TRAFO) that integrated different types of subject knowledge and made it easier for the council to comment on hearings and otherwise to influence traffic safety related decisions (see Englund 2000 and 2005). There is reason to believe that these organisational mechanisms contributed to the rapid spread of knowledge and the implementation of Aldnam's innovation.

3.3 TFD, TFB and PFF have funded the development

The council was laid down in 1971, and the research work was transferred to VTI and Chalmers. The research council's work was dealt with by the newly established Transportforskningsdelegationen (Swedish Transport Research Delegation)(TFD), and thereafter by TFB, KFB, PFF and VINNOVA.

Since 1971 a total of SEK 18.8 million (2004-kroner) has been spent on 19 projects concerning children and traffic. The majority of projects deal with children in traffic. The following four projects (for a total of SEK 4.3 million) deal with children in cars:

- CTH v/Aldman: Children in cars. Evaluation of restraint equipment for children in cars. 1983 -1984, TFD

- VTI v/Turbell: Swedish participation in the international work on child car seats. 1900, TFB
- CTH v/Løvsund: Children in cars: application rates for restraint systems for children. 1985-1993, TFB
- CTH/SAAB/Autoliv/Volvo/Folksam: Child safety in car accidents. 2003– 2006, PFF

Up to 1990, basis funding for VTI was around 90 % and research was thus – in contrast to today - scarcely dependent at all on client funding. Similarly the universities were not formerly dependent on external funding. The comprehensive activity related to restraining children in cars, see below, has been funded primarily through other public and private funds.

4 The role of the different subject environments

4.1 VTI's research - a basis for finding effects

In 1971 the former Vägtrafikinstitutet was expanded to become Väg- och trafikinstitutet (The Swedish National Road and Transport Research Insitute)(VTI) and took over parts of the Trafiksäkerhetsrådets research work and laboratory work, for example the medical laboratory. Thomas Turbell, who worked together with Aldman in the laboratory, was the leader of VTI's crash lab, which was responsible for testing child restraint equipment. VTI's work in the field of child restraints includes research (for example related to the use of equipment) follow-up of sample accidents, tests and participation in international standard development.

Aldman's innovation and the knowledge behind the advantages of rearward-facing seats alone have not been sufficient to ensure the use – and specifically the correct use – of this measure. Over the years VTI has carried out a number of related studies that have been important in identifying the effects of rearward-facing child car seats. Four such research themes where much work has been done in Sweden and abroad are:

1 Effects under different conditions – for example the child's' age versus length, any unexpected injuries, problems with airbags etc.
2 Lack of use of the products and effects of measures to increase usage. This has included looking at the effects of legislation, regulations and campaigns.
3 Incorrect use of the product, reasons for this and effects of measures to correct this such as campaigns, information and simplification of the system.

4 Product development, different types of seats and fastening systems, including standardising seats and fastenings.

Swedish research environments, especially VTI with Turbell, Arnberg and Anund as key players have carried out comprehensive studies within all these fields. The following can be mentioned:

1 The overlying effects of rearward-facing child seats are demonstrated by in-depth analyses, Swedish accident and insurance data and Volvo's accident database. (Turbell 1974, Arnberg and Ericsson 1976, Arnberg 1977, Arnberg 1978, Arnberg et al 1978, Carlsson et al 1987 and 1989 (?), Turbell 1989 and 1990, Kamren et al 1993 and Isaksson-Hellman 1997). It is shown that these seats must not be used in the front of the car unless the air bag is de-installed or disabled. (Forsman et al 2003). Others have demonstrated unexpected risks when using standard seat belts. (Bjørnstig et al 1997)

2 In Sweden seat belt use has been studied continuously since 1983 (Cedersund 2002). *The proportion of children being restrained* has increased from 20 % in 1983, to almost 60 % in 1986 when it became compulsory by law and almost 90 % toward the end of the 1990s.[2] The reasons why children are not restrained have also been studied, for example psychological reasons (Arnberg 1974) and the effects of special campaigns and information measures (for example Ekman et al 2001, Anund and Sörensen 2001).

3 Another major problem is that children are not restrained properly. This was studied by Tingvall (1987) with the help of interviews, observations and accident data and was later studied on several occasions at VTI. Both questionnaire surveys (Anund et al 1999) and observations (Nygren et al 1987, Anund 1998) show a incorrect-use rate of ca 40 % (non use + incorrect use)[3]. Incorrect use is higher amongst low-income groups and amongst immigrants. (Gustavsson et al 2003, Forward et al 2000). Far higher figures for incorrect use /lack of use are found in countries other than Sweden (Anund et al 2003)[4].

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[2] The Traffic Safety Handbook has meta-analysed seven studies of effects of the compulsory use of child restraints in cars (Elvik et al 1997). It was found that this leads to a decrease in the number of children injured of 15 %. In Norway the proportion of children restrained in cars increased from 42 % to 82 % when restraints became compulsory.

[3] It is important to distinguish between illegal use and incorrect use. In Norwegian studies, 3000 nursery school children were checked (Amundsen 2004). 5 % were not restrained at all, 5 % illegally restrained (standard seat belt) and 7 % incorrectly restrained (for example seat loosely fastened, child seat incorrectly placed, old seat, seat not compatible with type of car, air bag not disconnected in the front, belt across child's neck, belt across stomach only).

[4] Without an overview of what is regarded as incorrect use, it is difficult to compare countries

On the basis of this widespread incorrect usage, several Swedish researchers have recommended that child restraint equipment should be an integral part of a car's permanent fittings (Tingvall 1987, Anund et al 2003). Testing a *uniform fastening system* in cars (Berg and Gregersen 1992 and Berg 1998) shows that this type of system encourages increased usage and that ISOFIX works best.

VTI has a relatively large research group involved in the field and in recent years has produced a number of useful collections of knowledge. These have been referred to internationally for example in OECD’s key report ”Keeping Children Safe in Traffic” (OECD 2004) which otherwise focuses strongly on American and Canadian literature.

VTI was also drawn in as an advisor for studies in other countries. Trinca et al (1981) say that a comprehensive Australian study of rearward-facing seats started in 1978 on the initiative of the Road Trauma Committee of the Royal Australasian College of Surgeons and VTI contributed to this.[5]

4.2 VTI – a key role in standardising work etc

The connection between testing work, the laboratory and other research is seen as fundamental for the further development of equipment and practical application of the research results (VTI’s self evaluation 2006). At the same time, VTI notes that its role as an public authority means that it is less easy to work closely with industry or to develop products commercially than it is for other research groups.

VTI has worked closely with the authorities in a number of ways to evaluate actual measures and to provide an academic basis for the authorities’ decisions. The most recent example in the field of child safety is an assessment of whether child car seat installations should be inspected. In its allocation letter (Regleringsbrev) for 2006 the Government gave The Swedish Road Administration the task of assessing this. The Swedish Road Administration then gave VTI the task of developing the factual basis and analyses and conclusions were produced jointly in collaboration (see The Swedish Road Administration 2006).

[5]Australia has recently worked most on developing a forward facing seat.

Researchers from VTI (including Thomas Turbell) have taken part in national and international standardising work in the field. This work has primarily been published in the form of ”promemories” for the relevant authorities. Here the testing work forms an important foundation. This applies to examples such as

- The Swedish T-standard which is a mark of approval for the type of seat.[6] The T test is somewhat more stringent than the EU standard. Today only rearward-facing seats pass this test. VTI developed these standards in conjunction with TSV (Trafiksäkerhetsverket). The basis was VTI 's report 36 (Turbell 1974) which opened the way for crash tests with all types of available child equipment.
- VTI has also been involved in the work with EU-standards for child car seats. An ECE-directive (ECE R44) was adopted in 1981, and an increasing number of European countries are adopting it. The directive is updated regularly, most recently in 2006 (ECE R44/04).
- The work on fastening systems within the international standardising body ISO. VTI has had a leading role in this international work in developing the ISOFIX concept for simpler fixing for child seats (Turbell et al 2003). Participation was funded by TFB in 1990. ISO has also worked with the problem of crash cushions and child seats in the front of cars. According to Englund (2005) VTI was the first to study this problem in crash tests.

VTI's research on children in cars has been financed through its own funds (public basis funding) or funding from TFD, funding from the public administration (Vägverk, Trafiksäkerhetsverk/TSV, Skyltfond) and with fees from manufacturers who want to have their equipment tested.

4.3 Chalmers – little activity but taking up the theme now

When the Traffic Safety Research council was laid down, Chalmers acquired a new institution and a Chair in traffic safety research[7]. The latter was enabled with the help of a donation from Volvo. The post was held by Bertil Aldman who led the institution from 1972 – 1991 when he retired. The impact biomechanics research at the institution was strengthened in 1985 when Per Lövsund was recruited from VTI. At the same time funding was obtained from TFD for a doctorate on the subject of children in cars. This resulted in Claes Tingvall's (1987) thesis on ”Children in Cars” One employee at GM/SAAB is a doctoral student at Chalmers. Her research

[6] One difference is that the T-test also studies the equipment's ability to secure the child's head (Wenall 2003)
[7] The institute has changed its name several times over the years.

deals with child safety and she is responsible for Saab's child seats and child restraints.

From the middle of the 1980s, whiplash research was the dominant field at the institution and the area of child safety was laid down (Chalmers self-evaluation 2006). Work in the field has started again with funding from PFF and the EU and in co-operation with Volvo/Saab. Chalmers traffic safety institution is in close contact with industry through funding, co-operation on projects, associate professors and industrial doctoral students.

4.4 .Research in industry – on-going activity at Volvo

Volvo's own research unit has worked on child safety for many years, and has evaluated effects of different types of seats and fastening systems. Volvo has developed its own accident database and also carried out surveys on the use of the equipment and attitudes to safety. This gives the research group a good basis for analysis and is an important element in product development at Volvo. Volvo states that care for and profiling of safety for children is very significant if the market is to identify Volvo as a safe and attractive car.

Volvo's work has bee done in conjunction with researchers outside the institution. Volvo has also issued reports together with Swedish authorities and researchers from other subject environments, for example together with the former Trafiksäkerhetsverket (Norin et al 1980). Important knowledge that Volvo-researchers (Norin 1978, Norin et al 1978 and 1979, Isaksson-Hellman et al 1997, Jakobsson et al 2005) have contributed include the following;

- The use of different child restraint systems at different ages
- Degrees of injury when using different restrain systems
- Types of injury, parts of the body that are injured in different situations

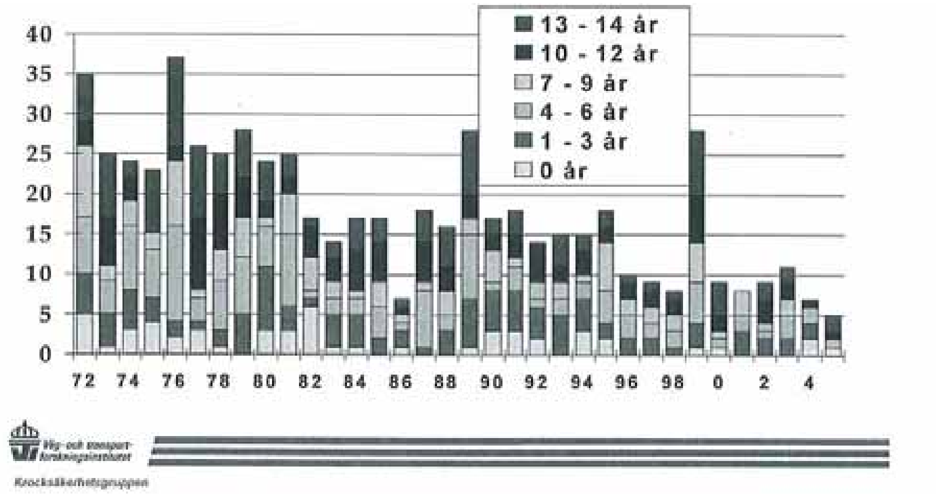
5 Social effects – major benefits for safety

5.1 Numbers killed in traffic accidents greatly reduced

It is well documented that different ways of restraining children in cars have been very significant both in Sweden and in other countries. In Sweden today very few children are killed when they are sitting in cars. While some 35 children below the age of 15 were killed in cars annually around 1970, the figure for 2000 was 5 – 10 children. For the youngest (<4 years) fewer than 5 children are killed each year, see figure 5.1. The number of seriously injured has also gone down considerably.

The Swedish Road Administration and VTI (2006) have looked more closely at Folksam's statistics for the 20 children under 6 years of age who were killed and the 30 who were seriously injured in the period 1996-2002. 18 % of the children who were killed or injured were not using restraint equipment. It is assumed that 9 children, i.e. around half would have survived if they had used rearward facing car seats. For the remainder, the crash was so bad that no form of restraint could have helped. Of the 30 seriously injured children, 12 would have incurred minor injuries or no injuries if they had been using rearward facing seats, For the rest, the seat position would have made no difference.

Figure 5.1: Accident development for children in cars from 1972 – 2005. Number of children killed in different age groups. Source: The Swedish Road Administration 2006.



5.2 Development of the Swedish ”Child car seat culture”

The foundation for these effects is also that the Swedish authorities have followed up knowledge development in the field with laws and rules (see Chapter 2), standardising work (see chapter 4.4), testing requirements for equipment, information measures etc.

The research environments have also played their part. For example, VTI proposed that the municipalities should take responsibility for ensuring that maternity hospitals could lend out seats for newborn babies. The thinking was that a recommendation from a person in a white coat would be followed by the parents. The counties of Värmland and Blekinge were the first to started, and by the 1980s the majority of Swedish hospitals had a system for lending out baby seats. This contributed strongly to increasing usage. Using the seat on the baby's very first car journey helped to establish good habits. The system is no longer in place but it was important for the introduction of baby seats and rearward-facing child car seats.

Safety organisations (such as NTF – Nationalföreningen för trafiksäkerhetens främjande) and the major car and equipment manufacturers have followed this up with recommendations. Up until, 2005 NTG had a national service telephone with advice on questions to do with traffic safety for children. Work was done with the health clinics, and courses were also held.

In the spring of 2006 a common national policy for restraining small children in cars was adopted, see appendix 2. The Swedish Road Administrations (2006) description of this policy points toward an important effect mechanism, the development of a common safety culture:

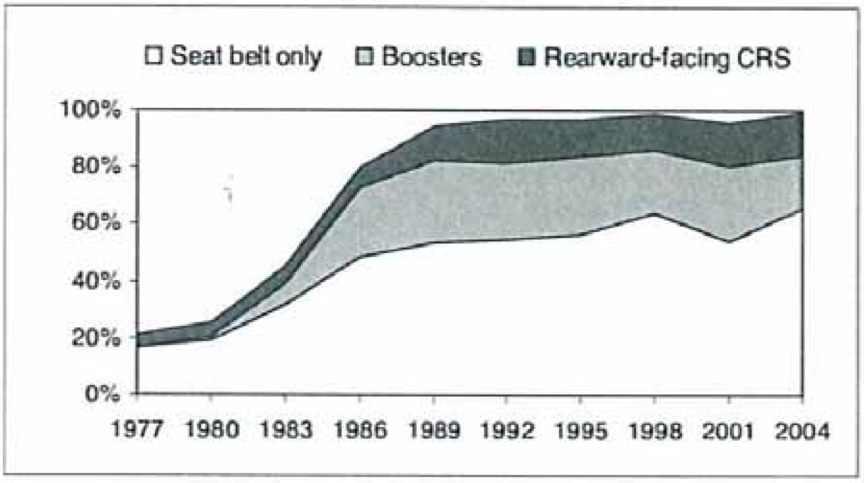
> *”Unique to this area of focus id that large pars of the car industry are behind it. This means that the risk of conflicting costs to customers is reduced, which in turn contributes to strengthening the Swedish child car seat culture”.*

An early social effect was the legislation requiring that child seats should be approved, which came as early as 1973 (Carlsson et al 1989). Today VTI is responsible for testing and The Swedish Road Administration for approving the seats. In connection with this VTI has a website with information about restraining children in cars with answers to frequently asked questions (FAQs) Sweden is also well ahead in restraining children who have grown out of the rearward-facing child car seat. Volvo launched the first seat belt cushion back in 1978

5.3 Use of restraints has increased

All this has contributed to a considerable increase in the general use of child restraints see figure 5.2. VTI's annual survey of the use of seat belts (Cedersund 2006) states usage of seat belts among children sitting on the back seat as 93.3 % in 2005. According to Anund et al (2003) and Anund (2003b) over 90 % of all children under 1 year of age in Sweden are restrained in cars using rearward facing child car sear. The proportion using a special child seat decreases with age, even though the seats produced today can take children up to the age of 4. 78 % of children aged 1-2 and 19 % of children aged 3 are secured using rearwards facing seats. These figures are from a survey of parents/guardians. It is likely that observation and controls would show that the figure is lower, see Amundsen (2004)

Figure 5.2: Proportion of restrained children below the age of 15 in Volvo cars in the period 1977 – 2004.



Source: Jakobsson et al (2005)

Since rearward-facing seats are recommended as the safest for 4 year olds and for longer for children who are small for their age, there is still great potential for increasing children's safety in cars.

6 The benefit is greater than the costs

6.1 The cost of buying child seats is around SEK 210 million annually

By the end of 2004 there were 392,539 children aged 0-3 years in Sweden. It is assumed that 95 % of them come from families that own a car, i.e. 372,912 children.

In the following analysis, it is assumed that the proportion that are restrained using rearward-facing seats is 95 % for children up to 1 year, 80 % for children 1-2 years and 20 % for children 3 years of age.[8] The required number of seats (assuming that 95 % are in families with cars) in order to restrain these children is 91,233 for children up to 1 year, 150.409 for children 1-2 years and 17.773 for children aged 3, a total of 259.415.[9]

[8] Here we use somewhat higher (1 and 2 % is not much higher) figures than Anund et al (2003) found, in that we include all seats in our calculations and not just rearward-facing seats.

[9] This shows that a seat is not necessary for each car. Anund et al (2003b) show that 50 % of those who have children between the age of 2 months and 9 years have two cars..

When calculating how many new seats need to be bought each year, it must be noted that many seats will be used by more than one child and the length of time that a child seat is used. The recommended lifetime for a seat is 10 years[10] and a seat could thus in principle be used by up to 3 children if we assume that each child uses the seat for about 3 years.

Anund (2003b) shows that 65 % of Swedish children have one or more siblings below the age of 10 from whom they could inherit a seat. In addition they may acquire seats from others or buy one second-hand. Anund (1998b) has shown that 48 % of child under the age of 1 used new safety equipment while the rest used seats that they had rented, acquired, inherited or borrowed. The corresponding figure for 1-2 year olds was 67 % and for 3-10 year olds it was 78 % (Anund 1998b).

If we use Anund's figures from 1998 for the proportion of new purchases, we need

0.48x91,233 + 0.67x150,409 + 0.78x17,.773

or a total of around 160.000 new seats to cover a child population's requirements. Given that each child uses the seat for three years, around 60.000 new seats will be required each year.

The price of seats varies by type and manufacturer. Baby seats are cheaper than seats for slightly bigger children. There are seats (for example from Folksam) that can be used from 0-4 years of age, so that there is no need to have two seats for each child. We have not calculated the number that have one or two seats respectively through the whole small child period, but assume that a new seat costs SEK 3.500. The annual costs of acquiring child car seats are therefore 3.500 x 60.000 = 210 million SEK.

6.2 Risk and injury figures with and without child restraints

The benefit of restraining children in cars can be estimated starting with the available risk figures. Unfortunately the most recent risk figures that cover children aged between 0-3 are relatively old and build on travel habits data for the years 1992-1995 (Thulin and Kronberg 1998). For children aged 1-3 years, exposure as a passenger in a car in the period 1992-1995 is given as 2,444 million person kilometres. The risk of injury is given as 0.052 injuries per million person kilometres. The risk of serious injury is given

[10] Defining the lifetime of safety equipment is complex. For child seats, VTI's crash labora-toty states a maximum of 10 years (Wenäll 2003), but this varies depending on what the seat has been exposed to.

as 0.007 per million vehicle kilometres. The risk of being killed is given as 0.0016 per million person kilometres.

In the following it is assumed that these risk figures are representative for children aged 0-3 years, even though they are calculated on the basis of data for children aged 1-3 years. The anticipated annual number of injured children can be calculated thus:

2444 x (4/3) x (105/95) x 0,052 = 187

Here the 2444 exposure in the period 1992-1995 is calculated in million person kilometres. The factor 4/3 is an expansion of the exposure from the group aged 1-3 years to the group aged 0-3 years. The factor 105/95 shows the growth in the total number of person kilometres by car from 1992-1995 to 2001 (source: SIKA's statistical year book). Similarly we can except the annual number of those seriously injured to be 25 and the anticipated annual number of fatalities to be 6. In 2004, the registered figures were 190 injured, 12 seriously injured and 4 killed. The registered figures can swing randomly around the anticipated figures. In the following the following rounded figures are used as a basis for the calculations:

- Anticipated annual number injured: 190
- Anticipated annual number seriously injured: 15
- Anticipated annual number killed: 5

These injury figures reflect the current level of restraining children in cars in Sweden. It is assumed that restraining children in cars is as shown in table 6.1. The estimates in the calculation are based on data from different Swedish studies referred to in earlier chapters.

Table 6.1: Proportion of small children (infants) in Sweden restrained using differ methods by age

	Age of child		
Restraint method	**0**	**1-2**	**3**
Child seat	95 %	80 %	20 %
Booster seat and belt	0 %	10 %	25 %
Seat belt	0 %	5 %	50 %
Not restrained	5 %	5 %	5 %
Total	100 %	100 %	100 %

What therefore is the benefit of restraining children in cars? How many fewer injuries and deaths are there today, with these levels of child restraints in cars than there would have been if no children were restrained in cars, particularly if no child car seats were used?

In order to answer this question, we start with the available figures for effects of restraining children in cars, shown in table 2.1. Here it is assumed that the majority of small children who are restrained using seats are in rearward-facing seats.

It is assumed that the risk of injury goes down by 80 % (all degrees of injury taken together). The effect of a booster cushion combined with a seat belt is set at 60 % reduction in injuries and the effect of seat belts alone is set at a 25 % reduction in injuries. Seat belts alone have a lesser effect on reducing injuries for small children than they do for larger children and adults. Current anticipated injury figures are shown in table 6.2.

Table 6.2: Current anticipated degree of injury for the 190 injured children aged 0-3. Give today's restraint levels.

	Age of child		
Degree of injury	**0**	**1-2**	**3**
Killed	2	2	1
Seriously injured	3	6	5
Minor injuries	40	87	44
All injuries	45	95	50

If for example children aged 0 were not restrained, the anticipated number of injuries would be:

$$[45 \times 0{,}95 \times (1/0{,}20)] + [45 \times 0{,}05] = 213{,}75 + 2{,}3 = 216{,}05 \approx 216$$

45 is today's number of injured children, 0,95 is the proportion that are restrained; 1/0.20 is the increase in risk if children were not restrained (corresponding to 80% reduction in risk). In a similar way, the anticipated numbers killed or injured if no children were restrained can be calculated for the other age groups. The result is shown in table 6.3.

Table 6.3: Anticipated degree of injury for children aged 0-3. Given that no children are restrained.

	Age of child		
Degree of injury	**0**	**1-2**	**3**
Killed	10	9	2
Seriously injured	14	26	12
Minor injuries	192	380	103
All injuries	216	415	117

In total it is calculated that without restraining children in cars, there would have been:

- 21 killed, i.e. 16 times more than today's anticipated number
- 52 seriously injured, i.e. 38 times more than today's anticipated number
- 675 minor injuries, i.e. 504 more than today's anticipated number

6.3 The benefit to society clearly exceeds the costs

The socio-economic costs of traffic injuries in Sweden are given by SIKA as follow:

- SEK 17.511.000 for one person killed
- SEK 3.124.000 for one person seriously injured
- SEK 175.000 for one person with minor injuries

The benefit of fewer deaths can be calculated thus:

17.511.000 x 16 x 2,775 = 777 mill SEK.

Here 17.511.000 is the cost of one death; 16 is the number of deaths that are avoided and 2,775 is the current value factor for 3 years with 4 % rate of interest for costing purposes annually. The benefit of fewer seriously injured is calculated at SEK 329 million. The benefit of fewer minor injuries is calculated at SEK 244 million. The total benefit is calculated at SEK 1 350 million. Annual investment in safety equipment is calculated at SEK 210 million. The calculation indicates that the benefit to society of child restraints in cars clearly exceeds the costs.

One question is whether research costs and the public costs of information etc should also be included. We can simply say that the benefits far exceed the public research resources that are set aside for this work.

One question is whether research costs and the public costs of information etc should also be included. We can simply say that the benefits far exceed the public research resources that are set aside for this work.

We have limited this to children under the age of 4, where the use of rear-ward-facing seats is specifically recommended. One possible additional calculation - provided that the data is available- would be to look at the under-7 age group who are also required to be restrained in cars. It may also possible to look at the social economy of everyone using recommended child seats. This type of approach would be useful in evaluating the benefit of extra input to increase the usage and also possibly for the commercial potential.

7 Commercial effects – utilised and potential

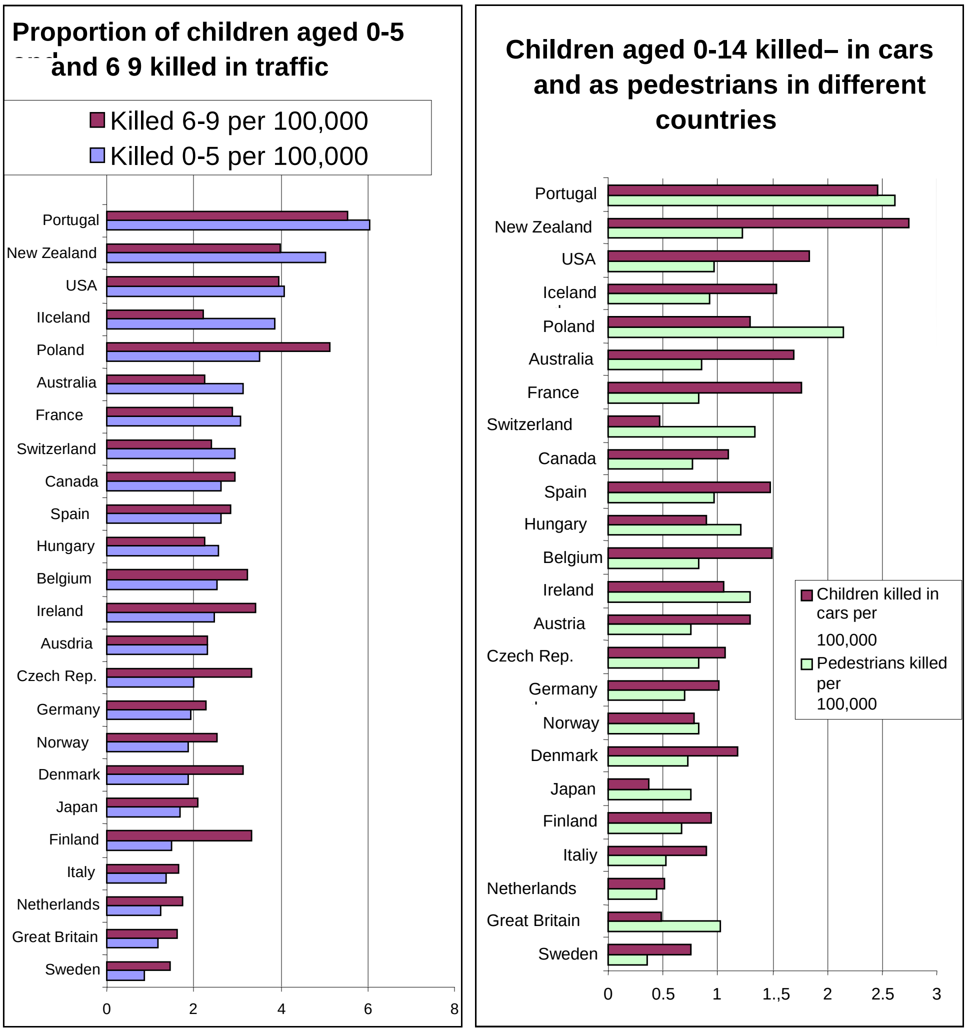
In interviews with representatives for Volvo and SAAB it became clear that child restraints are highly significant for the marketing of these makes of cars. Volvo sees very limited business economic gains from the sale of child seats in themselves.

7.1 Use of child car seats in other countries

There are major differences in practice between Sweden and other countries when it comes to the use of rearward-facing child seats. In the other Scandinavian countries the use of rearward-facing seats and other safety equipment is relatively high up to the age of 4 years, but clearly less than in Sweden. In Norway (Amundsen 2004) 39 % of 0-1 year olds and 20 % of 2 years olds use rearward-facing child car seats. In the rest of the world this seat model is used for very small children up to the age of 9 months/1 year and thereafter children are restrained in seats that face forwards or with booster seats and belts. (OECD 2004).

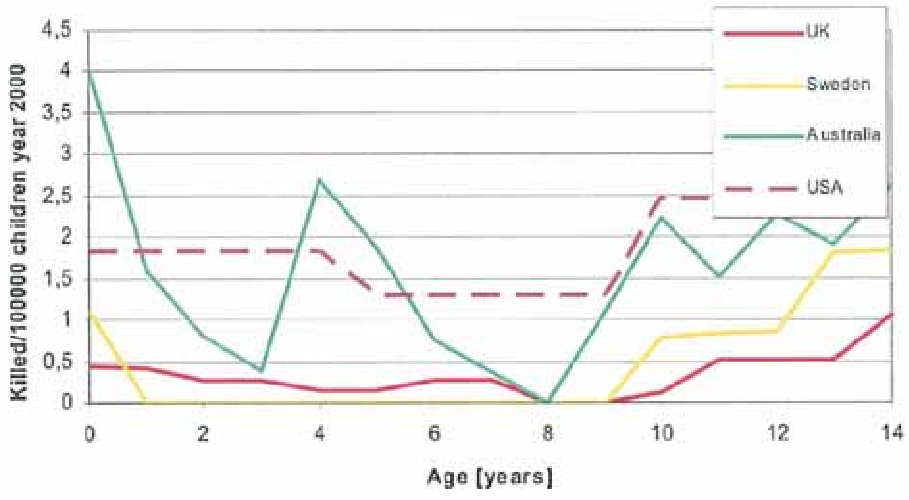
The Scandinavian countries have all had a good development with regard to accidents involving children in cars, and Sweden is particularly good with regard to the accident risk for children in different age groups and for children both in cars and in traffic, see figure 7.1. Countries that do not use the Swedish restraint models appear to have a higher accident risk rate for their children. This applies to the risk both of being killed and of being seriously injured, see figures 7.2 and 7.3. For example, an American study discussed by Gustavsson et al (2003) shows that 46 % of the children killed as passengers cars in 1997 were not using belts or other forms of restraint. A similar Swedish figure for children killed in cars between 1972 and 2002, is 18 %.

Figure 7.1: Risk of being killed in traffic in different OECD-countries for children in different age groups and for children under 14 as pedestrians and cars.



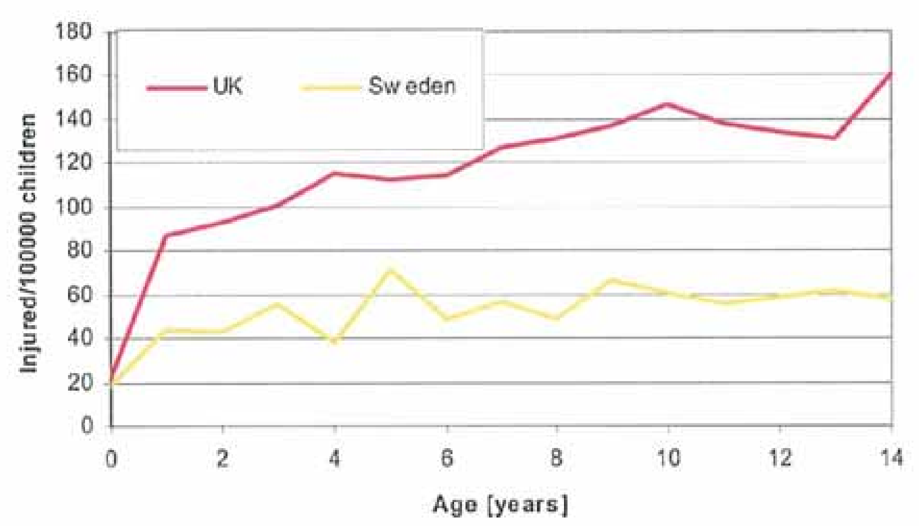
Source: IRTAD-database, figures given in OECD (2004)

Figure 7.2: Proportion of children killed per 100,000 in different age groups.



Source OECD (2004)

Figure 7.3: Proportion of children injured per 100,000 in different age groups.



Source OECD (2004).

7.2 The significance of Swedish knowledge development internationally

The fact that other countries use the Swedish restraint model to a lesser extent does not mean that children there are not restrained, but that for reasons of history and culture other models may be more suitable. Nonetheless, we can say that the Swedish child restraint research that contributed strongly to the use of restraints for children in cars was on the agenda.

The work with ISOFIX for quickly fixing child car seats in cars, see section 2.2, shows that international standardising work is important. The system has been developed by an ISO committee under Swedish leadership and is now common in new European, Japanese and Korean cars. ISOFIX is also found in American cars but there it is known as LATCH. In Swedish eyes, the aim is for there to be a common standard for fixing child seats, but not everyone agrees. Resistance comes from Australia, in particular, which Paine et al (2002) express as follows

> *"Remaining opposition to top tethers, which is now mostly German-researcher based, the unique CRS provisions is unfortunate but has no significant effect on the global adoption of top tethers."*

There may be several reasons why Swedish knowledge has not had an impact in all counties. A country's own industrial interests (car and equipment manufacturers) can pay a role and also because small countries/ language groups publish less and are therefore less visible internationally.

With regard to the latter, we see from the material we have obtained on child car seats that all authors refer primarily to other publications from their own country. There are few references to Swedish work in other countries' articles. References to Swedish work are usually to earlier works, while when the scope of articles on the theme increases, the gap between Swedish references is greater. However this is not a complete bibliometric analysis, an analysis that will also be made difficult by the fact that many of the earlier references are conference proceedings and not articles.

It seems clear that in addition to publishing it is important to participate in other forms of international work. This example shows that participation in internationalised standardising work and groups that can make recommendations (such as OECD) are particularly important for the practical transfer of knowledge. Swedish researchers, especially from VTI, have as mentioned in section 4.2, taken up this challenge over the years.

7.3 Marketing opportunities after GM's Love Seats

The first rearward-facing seats went on sale in Sweden at the end of the 1960s/ early 1970s, just a few years after Bertil Aldman published his research results and his proposals. According to Carlsson et al (1989) the concept was introduced in the USA a few years later by General Motors under the name of GM Infant Love Seats.

In Sweden the product received funding right from the start from authorities and traffic safety-organisations. The first Swedish laws requiring approval for systems for child restraints were issued in 1973, and in 1978 a law was passed that required restraints to be used for children up to the age of 4. In 1988 only a couple of percent of Swedish children aged between 0-4 were unrestrained in cars and the vast majority were restrained using rearward-facing seats or booster cushions. (Carlsson et al 1989.)

This means that a good deal of safety equipment and rearward-facing child seats is sold in Sweden every year. Some equipment, such as booster cushions, are now pre-installed in cars and the cost forms part of the cost of the car – whether the purchaser has children or not. An earlier system for lending out child equipment, see section 5.2, has ended without the reasons for this being made known. (Anund et al 2003).

From the start, the rearward-facing seats were produced in Sweden, primarily the Hyltestolen and the Klippanstolen. Volvo was also well ahead with its seat but has never had a great share of the market. (Information from Turbell, VTI). Today there are about 16 manufacturers to choose between in Sweden, and all are foreign. Production takes place in low cost countries such as Portugal and Asia, and the majority of seats are variants of forward-facing seats that are modified for rearward-facing installation. Volvo's child seats and integrated booster seats for original vehicle delivery are on the way according to Autoliv. Volvos child seats for ISOFIX are supplied by foreign manufacturers

7.4 Standardising increases usage – but is not a strategy for commercialisation

The development of restraint systems for children also includes other elements. For example this applies to fastening systems in cars, which are essential if the seat is to be used correctly and for the measure to have effects. The majority of child restrain systems were initially designed with a view to being installed using the car's safety belt. However other systems have been developed. With a common international fastening system, a good child car seat can easily be used in various different makes of car.

Sweden has had an important role in the international standardising work with ISO that began in the 1980s and is still on-going, The IS O group ISO/TC22/SC12/WG1 that has worked with ISOFIX has always had a Swedish leader (Bjørn Lundell from Volvo) and a Swedish secretary (Peter Claeson from SIS). Furthermore, VTI's researchers have participated actively in this standardising work, including funding from TFB and The Swedish Road Administration. Folksam has also participated. See Turbell et al (2003) and Lundell et al (1991 and 1993) for experiences.

International standardising can be an important tool for spreading knowledge and for paving the way for use of effective measures. Standardising work is a common area of work where several countries participate and is partly a ”fight” to get ”your” system, that is to say that it is not always possible to trace the origin of what results from these types of processes and negotiations. Swedish research has clearly formed a basis for the Swedish contribution. VTI states that their contribution to the ISOFIX-work is a result of the testing work at the institute and that they have been at the forefront of the development (Self-evaluation VTI 2006). However it was never the plan to commercialise this. The condition for an international standard is that it is open and can be used by all. For 10 years. VTI had a trademark protection for the name ISOFIX in order to prevent the product being adopted by another manufacturer. VTI's role as a public authority for testing now means that they must carry out this work independently of specific comercial interests. The authority role can set limitations for opportunities to acquire income from commercial work.

8 Conclusions

Swedish research lies behind a ground breaking innovation that has been of major significance for the safety of children in cars, namely the rearward-facing child seat. The seat which was designed by Bertil Aldman distributes the forces in a collision along the back of the seat before they are transferred in a controlled way to the child’s body and used correctly lead to a reduction in the risk of serious injuries for children aged 0-4 of around 90 %. Aldman’s innovation also represented a revelation in the view of children in traffic in a wide extent. An awareness developed that children are not small adults and that they have different physical and psychological requirements. Safer traffic for children must be grounded in this fundamental fact.

This concept was soon followed up by authorities and manufacturers in Sweden, and after a few years the seat went on sale and laws were passed to make its use compulsory. This first restraint measure for children has also had a major international effect even though not all countries have chosen the same design that is common on Sweden. The lives of many children have been saved and the seriousness of many accidents has been reduced, both in Sweden and abroad, as a result of this research work.

Mechanisms that can contribute to explaining this success are:

- *The concept arose in an interdisciplinary environment* with good opportunities for testing different models. Several subject areas are often necessary to develop smart solutions. Technical, medical and behavioural research was vital in understanding the problem, developing a solution and overcoming barriers in order to achieve effects. If the technology is not used correctly, it will have little effect, that is to say that it is also important to understand users’ behaviour.

- *Knowledge alone is not sufficient to achieve effects.* The framework conditions in the Transport Research Council emphasised direct contact between research and practice. With members of important public authorities on the council, it was possible to influence laws and regulations. Contact with the car- and equipment industry (Englund 2005, Volvo's internet pages) also meant that production commenced relatively fast.
- When the institution where the innovation was made was laid down, *steps were put in place for the continuation in a number of specialist environments,* both at VTI and Chalmers. Even though there were no great resources to be had from the new research councils, TFD and its descendants, research at that time was not so dependent on this type of funding
- VTI's frameworks with high basis funding made it possible to study measures to increase the use of the new type of seat and to *lead to the right use of the product.* Understanding framework conditions for implementing innovations is an important key to success.
- VTI also enabled a positive connection between testing and research that meant that it was possible to work together on international standardising work and to develop new products, including the new ISOFIX fastening system.
- Chalmers for its part had close contact with Volvo Car Corporation, where research and development had being going on the whole time, even though Chalmers had focused more on whiplash injuries.

The challenges lie in the following:

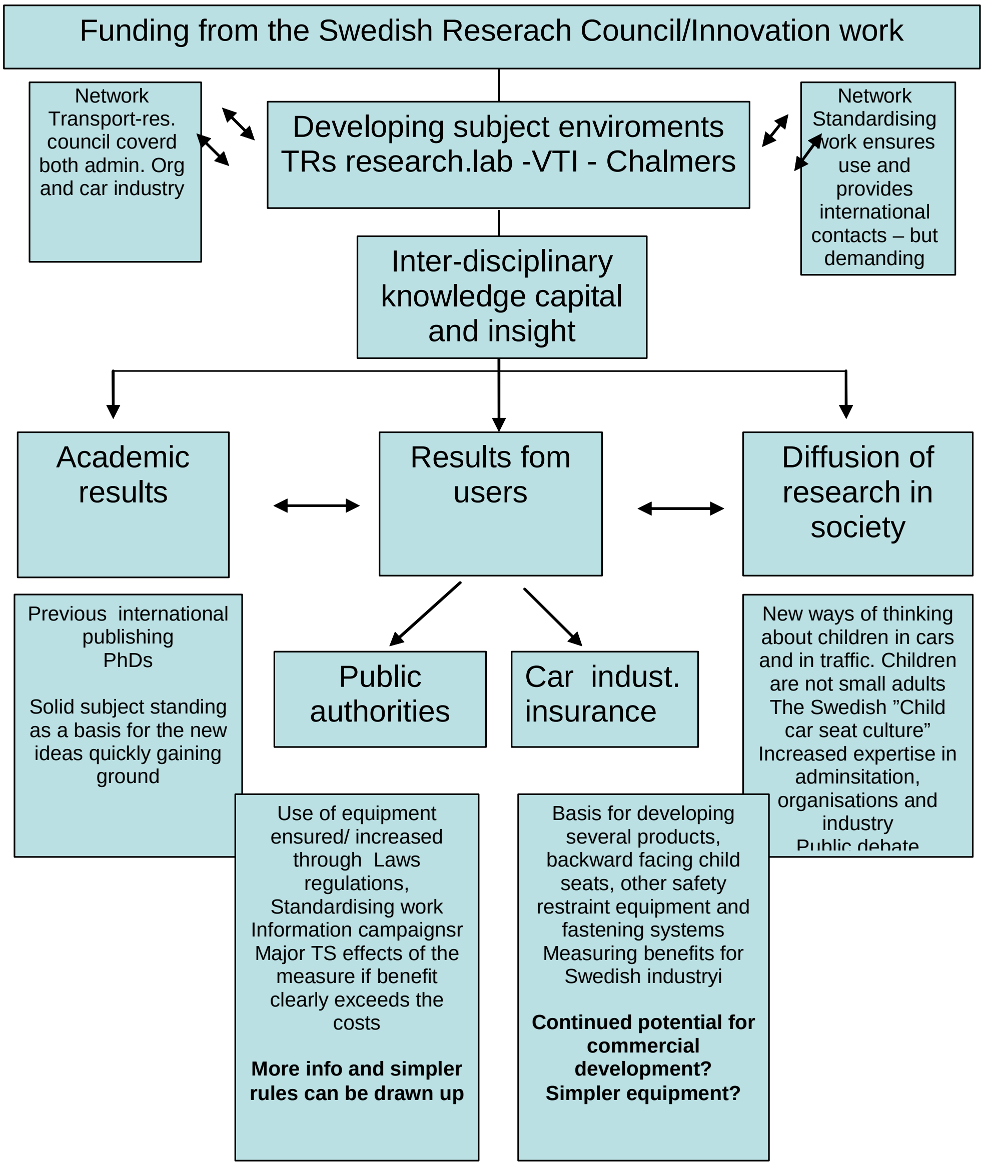
It is hard for small countries to succeed with their results where there is professional disagreement and where others have greater power in important decision-making bodies To influence and to pave the way for use of Swedish concepts and products requires resources (scientific and financial in order to participate in important fora)

- Public bodies may have formal problems in utilising objects for commercialisation. Close links with industry are vital for utilising knowledge in a commercial context.
- The framework conditions for both institutions and universities are becoming increasingly difficult. With less basis funding there are good reasons for increasing VINNOVA and PFF's contributions in this field, especially with regard to internationalising and marketing Swedish knowledge and research.

The use of the rearward-facing child car seat has resulted in major societal benefits. Since there are still many countries where the system is not used to the same extent, there is potential for both further societal benefits and for commercial interests. There is also a potential for developing the systems so that incorrect use is avoided. Better integration in cars is one possibility and measures for children with special needs is another challenge. There is also potential in better and simpler information for children's parents and guardians (better guidelines and clearer connections between legislation and recommendations).

Figure 8.1 shows the conclusions in relation to the effects study thought model. The model looks at publicly funded research. In addition there are also the resources that the car and equipment industry have put into product development.

Figure 8.1: Effects of publicly- funded research into the safety of children in cars – especially child seats – an illustration of effect chains



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Vägverkets föreskrifter (VVFS 1993:5)

Appendix A: Volvo's product development in the area of safety

Section related to child car seats marked in light blue

Safety – a never ending Volvo commitment

A tagline in a Volvo ad from the past stated, **"every year is a road safety year at Volvo".**

And the safety history of Volvo Car Corporation proves that this is true. The track record includes some 75 ground-braking safety innovations since the company was founded in 1927.

Volvo Car Corporation had a human-based philosophy already from the start. The founders of Volvo, Assar Gabrielsson and Gustaf Larson, stated:

> *"Cars are driven by people – the guiding principle behind everything we make at Volvo, therefore, is and must remain – safety."*

Safety cage and laminated windscreen

The safety cage and the laminated windscreen, both introduced in the Volvo PV 444 in the 1940's were among the first important safety features in Volvo cars.

The most prominent of all the innovations is of course the three-point safety belt in 1959, considered to be one of the most life-saving technical innovations in the history of mankind.

The first rearward-facing child safety seat prototype was developed and tested back in 1964 (introduced 1972) and the Side Impact Protection System from 1991 are a couple of other classic examples.

Own Road Accident Research Team

In 1970, Volvo Cars established its own Road Traffic Accident Research Team to study and learn from accidents involving Volvo cars. The team has injected vital knowledge into Volvo's research and development during its

35 years of operation. In recent years, the development of new safety features has continued, including world firsts in the Volvo S80, Volvo XC90, the all-new Volvo S40 and Volvo V50.

Safety innovations year by year

Here follows a complete list of all important safety features introduced during the history of Volvo Cars.

1940's
1944 Safety cage
1944 Laminated windscreen

1950's
1954 Defroster vents for windscreen
1956 Windscreen washers
1957 Anchor points for 2-point safety belts front
1958 Anchor points for 2-point safety belts rear
1959 3-point front safety belts standard

1960's
1960 Padded instrument panel
1964 Disc brakes front
1964 First rearward-facing child safety seat prototype tested
1966 Rear windscreen defroster
1966 Disc brakes all around
1966 Dual split triangular braking system
1966 Crumple zones front and rear
1966 Safety door-locks
1967 Safety belt rear seats
1968 Head restraints front
1969 Interior reel safety belts
1969 Heated rear windscreen

1970's
1971 Reminder safety belt
1972 3-point safety belts – rear
1972 Rearward-facing child safety seat
1972 Childproof locks on rear doors
1972 Warning lights (hazard)
1973 Side collision protection
1973 Collapsible steering wheel
1974 Energy absorbing bumpers
1974 Safe location of fuel tank
1974 Multistage impact absorbing steering column
1974 Bulb integrity sensor
1974 Headlight wiper/washer
1975 Day running lamps
1975 Braking system with stepped bore master cylinder
1978 Child safety booster cushion

1980's
1982 "Anti-submarining" protection
1982 Fog lamps front
1982 Fog lamps rear
1982 Warning lights in opened door
1982 Wide angle rear view mirror
1984 ABS anti-locking brakes
1985 ETC – Electronic Traction Control
1986 Brake lights in rear window
1986 Three-point safety belt centre rear seat
1987 Mechanical safety belt pre-tensioner
1987 Airbag – driver

1990's
1990 Integrated child safety cushion in centre rear seat
1991 SIPS – Side Impact Protection System
1991 Automatic height adjusting safety belt
1992 Reinforced rear seats in estate models
1992 Passenger airbag front
1993 Three-point inertia-reel safety belts - all rear positions
1994 SIPS-bag, side airbag
1995 DSA – Dynamic Stability Assistance
1995 Integrated child safety cushion outer rear seats
1997 ROPS – Roll Over Protection System (C70)
1998 WHIPS – Whiplash Protection System
1998 IC – Inflatable Curtain
1998 STC – Stability and Traction Control
1998 DSTC – Dynamic Stability and Traction Control
1998 EBD – Electronic Brake Distribution

2000's
2000 ISOFIX anchorages with rearward-facing child safety seat
2000 Dual Stage Airbag
2001 SCC – Volvo Safety Concept Car
2002 RSC – Roll Stability Control
2002 ROPS – Roll Over Protection System (XC90)
2002 New integrated child seat 2nd row (XC90)
2002 Lower Cross Member (XC90)
2002 New compatible front design (XC90)
2002 Safe 3rd row seats (XC90)
2002 New Front Structure (XC90)
2003 New Front Structure (S40, V50)
2003 IDIS – Intelligent Driver Information System
2004 BLIS – Blind Spot Information System
2004 Water repellent glass

50220/HÅ

The descriptions and data contained in this press material (release) apply to the international model range of Volvo Car Corporation. Specifications may vary from country to country and change without notice.

Appendix B: National recommendations from 25.4.2006

All the Swedish car manufacturers and organisations that work with safety signed the following recommendations on 25 April.2006 (NTF: 2006):

• Small children are safest in rearward-facing child car seats.
Our recommendation is that children should sit facing rearwards until the age of four or as long as possible.

• Locating the child car seat on the front or back passenger seat is equally effective from a crash safety perspective.
However the front seat often has greater leg room which means that children can go on facing rearwards as they get older. Therefore as far as possible, we should meet parents' requirements for accessibly to both the front and the back seats.

• We have a responsibility to provide information about putting children in baby seats, rearward facing child car seats, forward –facing booster seats and belts or belt cushions on a seat equipped with disabled passenger crash cushions.

• We have an active role in ensuring that all disabling of crash cushions should be done in a safe way so that the risk of wrong use of the system is minimised.

Other information about crash cushions
Children less than 140 cm in height should not sit in a seat equipped with a non-disabled passenger crash cushion.
Side crash cushions do not present any danger to children in rearward facing car seats, .The majority of forward facing child car seats help to keep the child in an upright position which means that the crash cushion may provide some protection.

The following have signed this declaration:

The Swedish Road Administration, Bilprovningen, VTI, Folksam, NTF, Scandinavian Safety, AKTA Graco, Autoliv, Volvo, Saab, WW, Skoda, Peugot and Hyundai

Transportøkonomisk institutt
Stiftelsen Norsk senter for samferdselsforskning

Working document dated 17.01.07
O-3165 TS Effect
Knut S Eriksen

SM/1833/2006
APPENDIX 5

APPENDIX 5
Case study: Developing better protection against whiplash and side-on collisions

Contents

1 Introduction

Much can be done to achieve a safer vehicle fleet. Amongst the measures that Swedish research has helped to develop are whiplash- protection and side protection for the head. Below we will summarise the project ”Effects of whiplash research in Sweden”, that was carried out in 2003 and 2004 and that presented some new information about side projection for the head.

Whiplash injuries are a serious health problem in Swedish society. According to Folksam, more that 2000 cases a year lead to medical invalidity.

From 1985 and up to the present day, VINNOVA and its predecessors TFB and KFB have funded research into whiplash through the Department of Applied Traffic Safety (TTS) at Chalmers. For 2003 the funding mostly went to planning purposes, given that the programme was seen to be in an intermediate phase. From 2004, the funding reverted to normal again. PFF (Programme Council for Vehicle Research) has funded whiplash research at Chalmers from 1994 to the present day.

VINNOVA has commissioned the Institute of Transport Economics, Oslo, and Møreforsking, Molde, to carry out an effects analysis of the whiplash research at Chalmers after 1985, where we look at the value to society, to businesses and to research. As far as possible the effects are quantified in kroner or using physical sizes and the research contribution is illustrated in an innovation system perspective. In order to respond to the mandate, we have chosen three different methodological approaches that each cover parts of the mandate and also supplement each other:

1. In the socio-economic analysis we attempt to quantify specific parts of the benefit in kronor for the standard Swedish citizen, for industry and outside Sweden, so that this can be set up against the costs. The benefit is made up of society’s willingness to pay to avoid accidents, loss of life and human suffering, management costs and administration.
2. The second method links us to a classic evaluation of an R&D institution where the aim is not to try to evaluate the actual institution in marketing terms, but rather to try and benchmark the institution against other similar R&D institutions where measures encompass a number of different dimensions.

3 In the private sector, the value of a company will not be determined on the basis of historic data but on future anticipated income. In its simplest form, the market value is the depreciated future cash flow that the market expects the R&D unit to be able to achieve. The R&D unit must then be able to prove, on the basis of its strategies, that it can reduce whiplash injuries further with the benefits that this can give in addition to moving research in new directions.

This document summaries the project ”Effects of whiplash injury research at Chalmers” that was carried out in 2004 (Eriksen et al 2004). In addition the information on side protection for the head has been updated to include the effect calculations.

2 Socio-economic analysis

2.1 Methodology

The benefit to society of effective protection against injuries falls into two parts. One is the benefit to the average citizen of some cars being of a higher quality. The other is the benefit to Swedish industry of increased exports of traffic safety products, or cars that contain these. This partially reflects the foreign benefit of these products, but is calculated using an entirely different product.

The method for calculating the benefit to consumers builds on the same methodological apparatus as is used in cost-benefit analyses of infrastructure investments in the transport sector. Here an attempt is made to measure the increased willingness to pay due to improvements in quality. This can be measured as a consumer surplus in that we assume that the improvement in quality is not deducted in the form of a price increase on the Swedish market.

The calculations build in part on SIKA’s recommendations for cost figures for injuries incurred in traffic accidents. Here a fatality is calculated as SEK 17.5 million; a serious injury as SEK 3.1 million and a minor injury as SEK 175,000. Whiplash injuries are difficult to fit into the standard injury pattern, but we have set the costs of a whiplash injury that lead to symptoms lasting for more than six months (serious whiplash) at SEK 2 million.

The benefit for Swedish industry is calculated in the form of increased value of the exports of these products to the world market.

2.2 Consumer benefit

Whiplash protection in the form of active protection in car seats and neck supports largely applies to the Swedish-produced Volvos and Saabs. The analysis is based on estimates from Folksam of the number of serious and minor whiplash injuries and five analyses of the injury reducing effect of 50 % for serious accidents and 20 % for the minor accidents.

The figure for Swedish cars with this type of protection is calculated to be 250 000 from when it was first introduced in 1997 and to the present day. We have concluded that the annual benefit per vehicle is an average of SEK 675. For the whole vehicle fleet, this comprises SEK 169 million. Depreciated over the whole lifetime of the car, 15 years, the benefit for Swedish consumers totals SEK 1900 million for the cars that have factory installed neck protection at present.

Retrospective fitting of whiplash protection has become a reality in recent years. In a joint project, Folksam and Autoliv have developed new whiplash-protection for retrospective fitting in the existing vehicle fleet. The cost of retrospective fitting is SEK 1000 per car. In order to estimate the effect of such a measure, Folksam allowed this whiplash protection to be installed in 8000 Toyota Corollas from the years 93 to 97. The provisional results indicate that the risk of injury for serious whiplash injuries is halved when whiplash protection is installed. This accords well with earlier calculations.

If we assume that retrospective installation of whiplash protection is feasible in 10 % of the Swedish car fleet of some 4 000 000 registered cars, i.e. 400 000 cars, it can be expected that without the measure there would be 200 serious neck injuries and 2000 minor injuries for this part of the car fleet. With whiplash protection this should go down to 100 serious injuries and 400 minor injuries respectively.

If we use the same cost evaluations as in Eriksen et al (2004), we achieve a saving in costs for Swedish society of a total of SEK 226 million once installation costs have been deducted. Depreciated over the remaining lifetime of the car (assumed to be 10 years) this amount is SEK 2040 million. On average per car with retrospective whiplash protection this amounts to SEK 564 per year and SEK 5105 after depreciation

Side protection for the head comes in various forms of head protection, including the ”inflatable curtain”. The development of these products has been closely associated with the research environment at Chalmers. Autoliv has been a market leader in this field. All Volvo and Saab cars have this form of protection. A new American study shows that these types of side protection reduce the risk of death in accidents by 45 %. We have estimated the reduction in serious injury accident to be half of this percentage. Based on the accident statistics, we have estimated the number killed in traffic due to side-on impacts and corner-on collisions. The number of cars in Sweden with different types of side protection for the head is estimated to be 460 000, but the figure is uncertain and it is estimated that it was at its peak in 2004 (later updated, see chapter 2.3.)

The calculation shows that the benefit per car annually was an average of SEK 305. For the whole car fleet this amounts to SEK 140 million and depreciated over the lifetime the vehicle this amounts to SEK 1600 million.

2.3 Updates on side impact protection

New types of side impact protection which give even better protection are in the process of being marketed. For example one type is designed to absorb the energy from impact no. two if this should occur within the next six seconds. Another type is stiffened so that it also provides protection in open cars.

The number of cars with side impact protection has increased considerably since the above calculations were carried out. More recent estimates indicate that the number of cars with side impact protection for the head is now around 1300 000.

This is a significant proportion of the car fleet in Sweden, and if we assume that these newer cars are driven slightly more than the average, we can see that they account for 35 % of the traffic work in Sweden. The calculations also show that the benefit per car per year is on average SEK 313. For the whole car fleet this is SEK 408 million and depreciated over the cars lifetime this amounts to about SEK 4650 million.

2.4 Value for industry

For Swedish industry the benefit consists of net increased sales value in the export market as a result of these improvements. On the basis of information from Autoliv we have estimated that this value is close to SEK 1200 per car. If we assume that 350 000 Swedish cars with this type of protection are exported each year, we get a benefit of SEK 420 million per year. If we add the annual benefit to Sweden of these pre-installed products we arrive at a total of around SEK 700 million. However there are problems in adding together figures that have been arrived at in such different ways.

The value of the head start for Swedish research depends very much on how long we believe this head start will last, which is very uncertain. For whiplash protection we have assumed that the head start will last for six years. Depreciated over 10 years this gives a benefit of SEK 13 billion. For side impact protection for the head, the advantage is estimated at two years. This gives a benefit of SEK 960 million after depreciation. The degree of uncertainty is high. In many cases we are lacking secure data. Hence sensitivity calculations have been carried out that show that the results are robust to changes in cost evaluations. See Eriksen et al (2004).

2.5 Costs

We have not succeeded in obtaining a complete overview of the cost of research and development that lies behind these products, Much of the problems lies in the difficulties in deciding and limiting which costs can be associated with which products. Contributions from state funding sources such as VINNOVA and PFF can be identified, but only form part of the whole. The total funding from PFF to the Department of Applied Traffic Safety (TTS) at Chalmers from 1994 to 2003 comprised SEK 26.4 million. Here industry contributed a matching amount so that the total extent of this venture was SEK 52.9 million. Chalmers' internally-funded share of the whiplash research is not known.

For VINNOVA and its predecessors the contribution was SEK 18.8 million from 1985 to 2003. Here double accounting should be noted and also that TTS has participated in other programmes.

For Saab and Volvo Car Corporation the development costs for whiplash protection are estimated at between SEK1.5 and 2 million annually from 1994 to 2003. This is our evaluation, based on discussions with representatives from the car industry. This is in addition to the pure research projects, see PFF above where Autoliv also participates. Autoliv is a research-based company that invests large sums of money in research and development. The proportion spent on whiplash measures is not known. Whiplash research has also been carried out at other research environments in Sweden. The financial scope of this is not known.

2.6 The USA – a calculation example

It is not just in Sweden that these safety products have been of major socio-economic significance. As an example of the effects for another Western country with high accident costs, we will use simplified conditions to look at the significance that similar whiplash protection, pre-installed in Saab- and Volvo-cars that are sold on the American market, has for the American consumer. We estimate that the accident- reducing effect is the same as for Saab and Volvo in Sweden.

The biggest difference between the USA and Scandinavia with regard to cars is car usage. With a population of 264 million there are some 133 million private cars, i.e. about the same density as in Sweden.

However the annual mileage per car is assumed to be far higher in the USA, which should be reflected in the accident statistics.

The evaluation of the benefit of avoided accidents is based on an article by Zaloshnja et al (2004). In order to improve the comparison basis with our earlier calculations, we have converted the figures to SEK and merged the two lowest American degrees of injury. Thus we obtain an evaluation of approx. SEK 3.5 million for a serious neck injury and SEK 200 000 for a minor neck injury. This is somewhat higher than we had used for Sweden (respectively SEK 2.0 million and SEK 175 000).

We do not have definite figures for the number of cars with pre-installed whiplash protection that are to be found on the American market, but here we estimate the total to be around 1 million. The total number of whiplash-injures in the USA is estimated by various sources to be 1 million annually. Of these, about 140 000 are estimated to be serious. We assume that, as for Sweden, the injury-reducing effect of whiplash protection in cars is 50 per cent for serious injuries and 20 percent for minor injuries. From our estimate of 1 000 000 cars the anticipated number of serious whiplash injuries would be 1037. With whiplash protection the anticipated number of injures would reduced by 519. Minor injuries would be reduced by 1274.

This implies an annual cost saving of SEK 2.1 billion. Depreciated over an assumed lifetime of 10 years for American cars, the total benefit for these cars would be SEK 18.7 billion. Per car the annual benefit is SEK 2 070 and depreciated over 10 years, this becomes SEK 18 700.

We can see that this is a considerably higher average benefit than for Sweden. This is due to a combination of an accident frequency that is twice as high annually and somewhat higher accident costs. Whether this higher accident frequency is realistic will not be discussed here but it is clear that cars that are driven more are more exposed to accidents. It is not known what the picture is like in other countries, but Sweden is assumed to be more like the rest of Europe than the USA is.

2.7 Summary

The degree of uncertainty in these calculations is high. Hence sensitivity calculations have been carried out (se Eriksen et al 2004), that show that the calculations are very robust with regard to the costs elements and the injury reducing effect.

The main impression is that there are **major socio-economic benefits** from the injury protection systems that are described above. No attempts have been made to set up new cost- benefit ratios for these measure, since we only have an overview of parts of the cost picture. However it is not really likely that the costs will approach the socio-economic benefit.

The analyses do not take account of the potential for future benefits of these measures as their use increases or of opportunities for related products from the same environment.

3 Result measurements for TTS

TTS’s goal is to carry out fundamental research and more applied research targeted at users such as Volvo and Saab. TTS is required to carry out teaching at fundamental, research and further education levels and has a separate budget for these activities. A third goal is the dissemination of knowledge through participation in the general social debate.

3.1 Teaching

One indicator of goal achievement in fundamental research is the examination of doctoral candidates. Since1985, 15 candidates have been examined, of whom 5 are now employed at Chalmers, 3 in the Swedish car industry (including equipment), 5 in the car industry abroad and 2 at research institutions in other countries. Almost half of the doctoral students have gone abroad and this is a high proportion. Although 1/3 have gone to Chalmers, this is not a particularly high figure. This doctoral education is a very important contribution to disseminating research knowledge to industry, but only 1/5 of the candidates have gone into Swedish industry . TTS has a staff of 7 researchers and less than 1 doctoral student per year is not very much. The education of the different candidates is described in the self-evaluation as the most important product. TFB/KFB was an important source of funding in getting the first doctoral students.

3.2 Fundamental research

Another important indicator of the participation of TTS in fundamental research is publishing in recognised refereed journals. In 2003 there were 8 such publications which is reasonably good in relation to the size of the institution, especially as half of these were in publications that set the highest demands for quality, the most prestigious journals. Two were picked out as publications that should be promoted. Evaluated on the basis of publications, it appears that a good level is being maintained in fundamental research based on the volume and the quality of the journals where the publications appear. Together with an average of two doctoral students a year in recent years, this indicates a good level of participation on the fundamental research side.

Basis funding for teaching comes from the state and there is a balance in the budget for teaching. The externally funded research has increased by 50 % in the period from 2001 to 2003. This strong growth hides a problem with the development of fundamental research in that the funding for fundamental research has been reduced from 50 % down to 14 %. Between 1985 and 2002, TFB/KFB/VINNOVA contributed ordinary funding for both fundamental research and project-oriented research.

There is greater dependence on project funding from PFF that comes though industrial partners and EU projects. PFF’s support has been of major significance for the collaboration between industry and this needs-motivated fundamental research. This close co-operation between industry and research, where people have been ”forced” to work together, has been experienced by both parties as very fruitful. However, dependency on this type of funding makes the group more vulnerable to fluctuations in funding while at the same time less focus can be given to fundamental research.

The fact that TFB/KFB stepped in and funded the work of TTS in the start up phase was probably highly significant for the research programme into whiplash research ever getting off the ground. At that time, Per Lövsund and his group did not have sufficient academic standing to obtain funding from the normal funding sources for university research. The co-operation between TTS and the research councils (TFB/KFB/ VINNOVA) that was not primarily targeted at fundamentals research has been described as very positive and fruitful by both parties.

Up until now it seems that the fundamental research side has been relatively successful. There is a clear opinion that to date TTS has been and is a world leader in the area. This view is well supported by TTS’ partners in industry, Saab, Volvo and Autoliv. Weakening the fundamental research share of the work means that the work is more vulnerable, since this research forms the basis for the rest of the work.

The synergy in teaching and co-funding from public teaching funds reduces the problem to some extent, but industry is also indicating, through interviews, that it is less willing to fund fundamental research. This type of funding can only be transferred from the user environment to a limited extent. The client list that TTS demonstrates as a basis for external funding has only three users, Volvo, Saab and Autoliv in the last three years and this dependency on a small group of users with such a large share of the budget also indicates a degree of risk.

3.3 Research networks

Over time TTS has built up a significant research network both within the research environment and for the user environments. Participation in international conferences where work is refereed and presented as well as other research conferences, provides an indication of network development in the research system. In 2003, TTS participated in 9 such conferences with referees and 5 other conferences. In 2002 the figures were 8 and 2 respectively and in 2001 they were 10 and 2. On average, the researchers present their own work at 2 international conferences each year. This is not particularly high, but researchers attend the most important conferences.

Right since the start of this research, there has been a close network link with the car industry and today this network with Volvo, Saab and Autoliv is vital both for professional development and financially. In 2003 half the funding came from project co-operation that is paid for via these companies.

Folksam has also been a co-operating partner for many years. Other important national co-operation partners on the health-related side are Göteborg University, Karolinska Institutet and Lund University. Here co-operative partners are lacking for the important health related whiplash research that is going on at KTH. There is some collaboration with the whiplash-environment at Sahlgrenska in Göteborg. There is a long list of national and international collaborative partners. The latter are primarily involved in EU projects.

A significant research network has been developed over a long period of time that shows a high level of activity with both users and other research environments. TTS' co-operation with industry and other research institutions, especially within the Göteborg region appear to have been an important reason behind the progress of whiplash research at Chalmers. Funding from TFB/KFB/VINNOVA and PFF has been of decisive significance for this co-operation.

3.4 Product development

For whiplash research, a separate product has been developed, the physical model or dummy known as BioRID that is used within the industry and in academia and builds on the fundamental research within theoretical and physical models, test methods, criteria and head-back support. BioRID is commercially available with its own patent income. This dummy together with mathematical models, combined with knowledge of injury mechanisms and injury criteria, has quickly led to the development of protection systems at Volvo and Saab where SAHR and WHIPS have been fitted in their cars since 1998. Input has also gone into the development of systems for side impact protection and pedestrian protection which are now on sale from Autoliv.

3.5 Summary

In summarising this measurement of TTS using different types of indicators, we can say that they stand out reasonably well as a fundamental research environment with regard to international publications in recognised journals with an average of one good published per researcher and with an average of two doctoral students in the last two years. They also take part in teaching at a lower level and contribute to the dissemination of knowledge about safety research with the synergy the research has for this teaching. They can document the development of a significant research network which nonetheless could be further strengthened with elements of the leading medical whiplash research in Sweden. To date they appear to keep a good balance between fundamental research and applied research and can show significant financial benefits from the products they have helped to develop for Volvo, Saab and Autoliv. Their financial vulnerability has increased in recent years due to a large drop in the fundamental research’s share of the work, which means that fundamental research may be damaged in the future. This vulnerably is strengthened by the financial dependency on just a few customers in Sweden, which are largely American-owned, and on EU projects that are often underfinanced, as a rule with just 50 %.

4 The value of TTS based on expectations of future added value through research results

In the self-assessment, TTS is challenged to go through its strategic thinking to see how its research can be strengthened in the future. The value of what is developed though research expertise is not what has already been created, but what can be expected to be created in the future with this expertise base and the network they have. Impact biodynamic research is the core expertise that has been developed band which comprises the fundamental research that will also mean most for applied research and for the further benefit of the user. Model development, simulations, optimising and use of algorithms in complex systems form important building blocks for fundamental research at TTS.

The tradition has been for research within what has been described as passive safety. It is clear from the strategic plan that we are now talking about a paradigm shift towards more active safety and a broader approach to the problem, especially towards a more inter-disciplinary approach where medical research is given greater priority. This is also the trend internationally.

4.1 Regional research co-operation

TTS is now working actively to develop this wider application and inter-disciplinary approach to its research by developing a larger centre of expertise for safety research, GVSCC (Göteborg Vehicle Safety Centre at Chalmers), now known has SAFER. The main base of this centre appears to be Chalmers, but there is a significant expansion of the expertise environment and there are links with all the relevant players in order to develop a more complete innovation system in the region. It has financial links to VINNOVA's announcement of research funding, VINN EX 2003.

The intention is to maintain and create new world-leading inter-disciplinary fundamental research, to link together industry/research/society in useful collaborative projects, to create first class teaching at all levels, to contribute to recruitment for industry and to act as a meeting point for all relevant players. Both Volvo and Saab are currently ”Centres of Excellence” within research and development in safety within their international companies. This new centre of expertise is also part of a strategy to strengthen this research within the company. They live with on-going competition with the quality of where the research is located.

TTS is contributing its expertise base within the development of SAFER to ensure this wider approach which in turn will extend their expertise base. There will always be risks if people want to go on achieving equally good results in the future with the research we have seen to date. We cannot know for certain whether this research will lead to reducing the number of serious whiplash injuries even further, provide benefits for the car industry, or generate high value spin-offs in areas we cannot see today.

4.2 The value of the research

In order to evaluate the value of the research based on future benefits, a parallel is drawn with how a newly established R&D company would be valued on the Stock Exchange. This form of added value will always be looking forward and making predictions about the income that will be generated in the future in order to meet the expenses of today. The present value of the future net cash flow will be the value of this R&D company. In the analysis, it will be important to evaluate whether the expertise that has been built up has the potential to improve this type of preventative measure further through research so that the extent of injuries goes down even more. It will still be the quality of the fundamental research that is the most important criterion for TTS to succeed. However all the emphasis on developing fundamental research in order to harvest future benefits is marked with a high level of risk. The funding institutions ability to think long term is therefore decisive.

5 The significance of the funding system

Central personnel within different areas of vehicle –related research, the car industry and research funding have expressed their views on how the existing funding systems work.

With regard to **fundamental research** the dominant attitude is that a large part of the research would not have happened had it not been for the funding from VINNOVA and its predecessors. 100 % funding of fundamental research is vital for being able to focus on achieving results that can be expanded and adapted for research and product development. The significance of VINNOVA and its predecessors for targeted yet fundamental research is emphasised.

For whiplash injury research, the funding from VINNOVA and its predecessors has been of decisive significance. The significance of this focus was understood at an early stage by central personnel within VINNOVA's predecessor TFB, and the funding of TTS' fundamental research came for the most part from TFB/KFB/VINNOVA.

The **applied or adapted** research was previously funded by TFB/KFB, but is now funded by a user-steered system, PFF, where the car industry and the state each contribute 50%.

The majority appear to think that this system works outstandingly well. It is noted that for the supplier industry in particular, usually the small and medium sized businesses, the research contribution has gone from next to nothing to having significant scope. However it is also noted that there is still a long way to go before a satisfactory level is achieved, Opinion is divided as to whether the system has led to more effective research or whether only the scope has increased.

The main weight of the research for the small businesses has gone in the direction of product development, while for the larger companies it has often been more towards more fundamental research. Many of the small companies experience part funding as essential for research to take place, while the larger companies research had generally come later and was of a more limited scope, Stimulating **positive interaction effects** at different levels has been an important motive in setting up the user –steered model but has also played an important role for VINNOVA/TFB/KFB.

User steering and part funding have clearly led to better co-operation between industry and the research institutions The fact that the company is formally the applicant, while in many cases it is the researchers who have the ideas, lead to an effective exchange of information. Trust enhances co-operation while withholding information does not appear to have been a problem at all.

Co-operation between major ventures leads to a from of horizontal collaboration on measurement methods, standards and shared tools such as BioRID-dummies. At this level the co-operation works very well, helped by the funding systems. Co-operation on products between major companies is limited by competition.

The small companies have often worked with a larger company to improve a product that the smaller company supplies to the larger one.

Interaction between funding partners is also significant. Even though both VINNOVA and PFF for example largely play a 'behind the scenes' role, they can act as a catalyst for the smaller companies in bringing together companies and researchers.

The interaction between the fundamentals research and the adapted research which borders on product development is regarded as essential if product development is to take place. Industry highlights its needs which also include projects of a more fundamental nature.

The impression is that co-operation between all types of players on the same level or on different levels within car research often leads to greater effectiveness and synergy in that everybody is working towards a common goal. Under less fortunate circumstances, however, such co-operation can lead to increased bureaucracy, internal competition and coordination problems. However several note that nationally funded projects e.g. by VINNOVA and PFF, stand out favourably in relation to international projects. VINNOVA and PFF are regarded by many as non-bureaucratic and flexible organisations.

6 Conclusions

The significance of whiplash measures for society are indicated through the socio-economic analyses of the traffic safety products that have been developed and taken into use. We now know that these measures are working through a number of major Swedish and American studies.

In all, the value of lives saved and the reduction in human suffering, health costs and material costs, as well as loss of production amount to significantly higher values than those that are ascribed to research and product development. The size of the research and development costs is uncertain, since we only know externally-funded amounts in kroner, and not what the research institutions and industry have used ”from their own pocket”. However, the benefits far exceed what can reasonably be assumed to be the use of resources, so that there is no doubt that these are highly profitable investments for society.

Side impact protection and crash cushions are important products for traffic safety in the last decade. Systems for side impact protection are technically-advanced products that require a deep insight into biomechanics and highly developed technological expertise. The use of side impact cushions has made a significant contribution to improving traffic safety.

Side impact protection in cars can involve the car’s body, with doors that can withstand penetration and internal protection against injuries. About 1,300,000 Swedish cars have side protection for the head. The societal benefit of cars in Sweden having side impact cushions is around 310 per car and making an annual total of SEK 410 million.

The value to Swedish industry which manufactures side impact cushions and other advanced safety equipment lies in significant sales at home and abroad. For the Swedish car manufacturer, the value of safety equipment such as side impact protection lies primarily in Volvo and SAAB being regarded as safe, attractive cars. The ability to offer safe and attractive cars has been and remains a very important sales argument for Volvo and SAAB.

The research at Chalmers Technological University has occupied and still occupies a central position in the development of physical safety equipment with a broad spectrum of products. Co-operation between researchers, funding institutions and industry has proved to be effective and has resulted in new and creative solutions for the Swedish car industry. The contribution to fundamental research from VINNOVA and its predecessors has been and remains a catalyst which has led to this co-operation, and together with PFF has contributed to product development and added value within Swedish industry.

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APPENDIX 6
Case study: More effective police controls/ police enforcement against speeding and drink-driving

Contents

1 Introduction

Until the transition to driving on the right in 1967, Sweden had no speed limit outside towns. From 1967 speed limits were introduced, firstly as a trial scheme and then as a permanent arrangement from 1979. During the period between 1967-1979, a number of speed limit trials were carried out that were evaluated by VTI. These trials showed the major significance of speed for traffic safety and in due course led to the development of the so-called ”power model” for describing the connection between speed and traffic safety. (Nilsson 2004). This model is also recognised internationally. Ultimately it was realised that exceeding the speed limit is a major traffic safety problem. This formed an important part of the background for research into how effective police enforcement could be set up to reduce speeding.

In order to reduce the speed level to a level that is suitable for different situations, a broad spectrum of measures targeted at road users, roads systems and vehicles is required. A number of Swedish subject environments have contributed to the research basis for this work. In this case study, we will focus on one specific area within the work on speed limits – namely developing effective police enforcement. We will look at one research environment, namely the Department of Psychology at Uppsala University.

2 Research into police enforcement at the Department of Psychology, UiU

Research into the effect of police enforcement has a relatively long history in Sweden, beginning as early as the 1960s. (See for example Ekström, Kritz and Strömgren, 1966). The research that took place at the Department of Psychology at the University of Uppsala began at the end of the 1970s when the institution was linked to a research programme into police enforcement financed by TFD (established in co-operation with The National Police Board, The Swedish Road Administration and The National Traffic Safety Administration) and became members of *Kommitten för Övervakning och Påföljd.*

Much of the research at Uppsala dealt with experienced or subjective accident and detection risk, in connection with breaking the speed limit and drink driving. Part of the aim was to find to whether the subjective risk was of a measurable size, and what relationship this had to the objective risk of detection. The research was led by Professor Lars Åberg, and carried out in co-operation with a varying group of co-workers.

Much of the research (two or three projects) in connection with speeding and drink driving was carried out in co-operation with researchers from the consultancy company TOS-AB in Stockholm. The research has also been carried out partly in conjunction with VTI. In the Nordic studies work was carried out in collaboration with TØI in Norge, *Trafikskyddet* and VTT in Finland and with *Rådet for Trafikksikkerhed* in Denmark.

The first project carried out in Uppsala within the field was a literature study and a survey of the knowledge situation within the field (TFD, 1980). Thereafter the institute took part in a project on the long term effects of enforcement (TFD, 1983) that showed amongst other things that long-term enforcement input on roads with a 90 km/hour sped limit had effects on the risk detection, on behaviour and on accident figures.

Nilsson and Åberg (1986) give results from two evaluations, where one evaluates the effect on speeding while the other evaluates the effects on accidents. The analysis results showed that on stretches of road with at least twice the level of enforcement, there was a statistically significant reduction in the proportion of accidents between vehicles of 13%. On two stretches with two and five times the normal level of enforcement respectively there was a reduction in the number of accidents of about 19%. No effect was observed on single vehicle accidents.

Research was also carried out on roads with a speed limit of 30 km/hr (Åberg, Haglund, 1989) and here it was also noted that police enforcement has clear effects both on the risk of detection and on behaviour. The average speed at 30 km/hr was significantly lower on the monitored stretches of road that on roads without police monitoring. Driver interviews showed that 92 % of those questioned drove these stretches of road at least once a week. Of the drivers on the monitored roads, 71% said that they had seen police checks in the last three years while only 8% on the non-monitored roads had seen them. When asked about the drivers evaluation of risk of being stopped for speeding, 57 % on the non-monitored roads said that the risk was less than once per year, while only 30% on the monitored stretch estimated the probability as being as low as this.

A study based on interviews, questionnaires and laboratory measurements (Åberg, Haglund, 1990) included the risk of detection. The significance of fines on choice of speed has also been studied (Åberg, Engdahl & Nilsson, 1989) as well as the significance of police margins when enforcing speed limits (Nilsson, Andersson, Haglund and Åberg in VTI's series).

Research has also been carried out at Uppsala on speed without evaluating police enforcement (for example Haglund, 2001). In addition some research has been done where the main aim was somewhat different, including a

Nordic project that compared speed adaptation in towns in Denmark, Finland, Norway and Sweden (Åberg, Larsen, Glad, Beilinson, 1998) and evaluation of an ISA project in Sweden (www.vitsa.se). In the projects, risk of detection was studied as one of a number of elements.

Police drink driving checks have also been studied in areas that carry out breathalyser testing at varying intervals. Here the subjective and objective risk of detection and accident development have been studied and the results demonstrated that drivers were aware of the enforcement and that increased enforcement had effects on the accident figures (Åberg, Engdahl, Nilsson, 1986). Later a major study was carried out using questionnaires (answers from 2500 respondents were used) on drivers' opinions of drink driving checks, and of their own behaviour in connection with alcohol and driving (Åberg, 1990). A joint Nordic project studied the relationship between the risk of detection and self reported behaviour (Åberg, Glad, Bernhoft, Mäki, 1990).

It can be somewhat problematic to calculate how much funding the environment at Uppsala has received from VINNOVA and its predecessor for this research, given that the field is not entirely distinct from other research areas at the institution. Some of the finding was used for evaluating measures, which could be regarded as a separate task rather than as development of a research field. On the other hand the subject environment has been given resources for general knowledge development of relevance for the theme of enforcement. Examples of more general research themes of significance carried out to understand driver behaviour and possible effects of different forms of control are: Incorrect driving, Attitudes and safety, Models for driver perception of distance, Models for information processing and decision making, Formal and informal traffic rules. In all the research has received SEK 26 479 415 in funding. This includes funding to TOS AB for two of the projects.

Note however that the research field of ”police enforcement” is relatively widely defined, so that it could be argued that fewer projects should be included and hence the total sum would be significantly lower. A complete list of the projects that were included can be found in the appendix.

3 References to and interpretation of the research in recent literature

In the *Traffic safety handbook* chapter 8, which deals with enforcement and sanctions, reference is made to the research at Uppsala (Nilsson and Åberg, 1986) in connection with studies of the significance of levels of fines on speeding and average speeds. Reference is also made to Åberg, Engdahl and Nilsson (1989), as one of relatively few in-depth discussions of the effects of fines that has been published internationally. There is also a reference to Åberg, Engdahl and Nilsson, (1986) in connection with studies of drink driving enforcement.

Vaa (1995) is a report commissioned by the Norwegian Directorate of Public Roads that is intended to bring together relevant information about measures that influence road users choice of speed, in order to use this as a basis for an effective traffic monitoring strategy for the police in Norway. This report is based on literature studies and also uses references from the Traffic Safety Handbook and other material. This report goes through the relevant publications in relatively great detail, in order to identify strengths and weaknesses of the studies and to draw out the relevant information. The report covers three different publications from the research group in Uppsala.

1 Åberg, L., Haglund, M. 1989 Övervakning i tätort. Hastighetsanpassning på *vägar med temporär begränsning till 30 km/h*. TFB-meddelande 95

Here Vaa concludes that:

> *”One of the most interesting things about this study is that even these very low levels of enforcement appear to have effects – both on the subjective risk of detection and on the choice of driving speed. However we believe that care should be taken when generalising these results. There may be a question of homogeneity, perhaps limited residential areas with a lot of local traffic and little long distance traffic. The fact that 92 % of the drivers use this stretch at least once a week itself indicates that even with few speeds checks a relatively high number of drivers who use the roads have noticed the checks. (…) A reasonable conclusion may therefore be that the amount and quantity of enforcement appears to give effects within limited, homogenous areas but presumably not in other, more heterogeneous residential and urban areas, let alone outside densely populated areas with different speed limits and a different composition of local and long distance traffic”*

In other words, this study maintains that a very low level of enforcement has effects on speed and that this type of measure would have greater effects if it were directed at local and commuter traffic.

- Nilsson and Åberg (1986): Övervakning och påföljd. TFD-forskning 1976-1983. Stockholm, TFB, 1986 (TFB-rapport 1986-11) presents results of intensive enforcement on roads outside densely populated areas and with a speed limit of 90 km/hour.

Vaa’s interpretation of the results of this study is as follows:

> *”The analyses showed a statistically significant difference in the number of driver above 105 km/hr. The proportion of drivers above 100 km/hr was 40 % lower in the experimental group. The authors' explanation why the effect first becomes apparent at 105 km/t was that road users are aware that the speed limit needs to be exceeded by a minimum of 10 km per hour before a driver is stopped by radar control on 90km/hour stretches. (…) One possible explanation for the reduced accident figures may be a reduction in the number of accidents when overtaking due to reduced variation in speed distribution. The authors note that the results can only be generalised for roads with speed limits up to 90 km/hour. The demonstrated reduction in accident figures apply to specific "accident black spot" stretches of roads. It is not therefore necessarily the case that similar results will be achieved on road with more "normal" accident figures.”*

Based on the 15 studies of stationary speed checks that are considered in the report, whereof the publications from the environment at Uppsala comprise two, Vaa concludes that:

> *”The underlying trend in the studies is a clear and consist tendency for stationary speed checks to reduced average speeds, the number of speeding offences and/or spread. Several studies also show a reduction in accidents. Effects of mobile speed enforcements have not been documented: the effects of these occur only in combination with stationary forms of enforcement. Nor have the effects of enforcement using unmarked police cars been documented. However, this form of enforcement has not been satisfactory studied.”.*

While it is difficult to allocate the ”glory" for the spread of this type of research results, it is clear that the research results from Uppsala are a significant factor in themselves in relation to the available quantity of this kind of study. It may be even more important that the total quantity of studies together provide considerable weight which means that the authorities can now see that police enforcement is an effective way to fight accidents, given that increased enforcement leads to reduced average speeds etc.

2 In addition, the report by Åberg, Engdahl and Nilsson (1989) in connection with the significance of fines and the size of fines for the choice of speed, was also studied. The conclusions from this study were that:

> *”The speed measurements indicate that doubling the fines has not led to any significant change in driving speed. The interview surveys show that only 1/3 of the drivers knew the size of the fines. Afterwards almost half the drivers suggested an amount that was too low. between 30 and 50 % knew that the fines had been increased. (…) The lack of effect may be due to the fact that many drivers did not know that the fines had been increased and that many underestimated the size of the fines. On the other hand it is probable that there would have been an effect on the speed measurements if drivers who know about the increase and size of the fines had been influenced by the increase in the fines.”.*

On the basis of this and one other (Swedish) study, Vaa concludes as follows:

> *”Based on these studies it obviously cannot be maintained that fines do not affect drivers’ choice of speed or that changes in the size of fines is entirely without effect. However it is probable that the effect of the fines depends on the level of enforcement. If there is no enforcement and the subjective risk of detection is zero, then the size of the fine is of no significance.”*

This quotation demonstrates how the studies work together – two studies are not sufficient to draw solid conclusions. Nonetheless these findings are sufficient to suggest reasonable areas of focus and how traffic safety work should be directed in the future.

In an Austrian literature study on driving under the influence of alcohol, reference is made to Åberg’s (1993) study of attitude changes in connection with a reduction in the drink driving limit in Sweden, as an indication that a lower drink driving limit can help to remove the social stigma of drink driving, so breaking the law is now seen as less serious.
(Kuratorium für Verkehrssicherheit, Vienna, 2003)

If we summarise on the background of this information, we can see that both the research into drink driving and the research into the subjective risk of detection in relation to the choice of speed must still be regarded as original research contributions which still have a role to play as part of a larger research corpus around these subject areas. The findings themselves are also still relevant.

Part of the research may also be regarded as methodologically interesting, in that it deals with the relationship between behaviour and self reported behaviour, for example, or the relationship between subjective and objective risk of detection. Even though this type of research cannot always be used directly in traffic safety work, knowledge of what can be drawn from different types of studies is decisive for carrying out effective research within the field of traffic safety in the future and is also contributes to a more satisfactory understanding of interaction within the traffic system.

4 Problems in determining the effects of the research

For various reasons, it is difficult to decide exactly the effects of the research on police enforcement that has been carried out by the institutes. Some of the reasons for the difficulty in revealing and determining the effects are:

1. **The research considered here to some extent goes back a long way**, compared with the normal horizons in traffic safety work. This means that it is difficult to trace some of the people who have used the research. It has been relatively time consuming to find some those who have been involved in this research in one way or another. Many of them are now retired or are working in completely different fields.[1]. Even those who can be traced may have problems in remembering the ways in which the research results affected their own work or the political decisions of the time. Many say they have problems in remembering this in detail, and even though this many not appear problematic, it is likely that the interpretation of events will be influenced by much of what has happened in subsequent years. As one of the interviewees put it: “Research is to some extent ‘fresh produce’ and much of it becomes less relevant and less interesting as society and attitudes change. Some of the measure may becomes more or less relevant based on whether the main emphasis is collective or individual. In other words the relevance of the research can also alter as a result of political rather than research-based challenges.

[1] For example, unfortunately it has not been possible to contact two people who were the Rikspolisstyrelsens representatives on the *Kommitteen för Övervakning och Påföljd*. Being in this position, they may have been able to provide a significant contribution towards understanding how the research carried out among the committee was spread and adopted by the police.

2 **The research also had an academic content**, that may make some kind of “translation work” necessary in order to be able to obtain the benefit for practical traffic safety work. This also means that part of the application could be in the form of so-called “ conceptual “ research use, which means that the results are not necessarily visible in the first instance.

3 **Much of the research was carried out in collaboration with other researchers and research groups**. This can make it difficult to decide which of the concrete projects and research results have had effects. This applies both to the collaborative projects, where it is difficult to distinguish one contribution from another (and where researchers will, in practice, influence each others work), and because political changes often come about as a result of a massive research input over time, where it has been possible to document the type of effects that measures will have. One single research project or one single study will seldom be sufficient to lead to practical or political measures. A number of studies in the same area , on the other hand, will, over time, produce sufficient momentum for such changes to be implemented. How the “glory” for such changes should be shared amongst the different research projects is still very unclear.

4 **Knowledge can also be of decisive significance as a basis for decisions even though it does not in itself lead to an increase in safety.** It is important for decision makers to know which measures have effects and how great this effect is. The significance of scientific knowledge as a decision basis for road policies has become increasingly strongly emphasised in recent years. A basis of scientifically-acquired knowledge will ensure both the effectiveness and the legitimacy of the measures. Similarly, it is also important to show which measures have had limited or no effects so that resources and attention can be focused on the areas where there is a real potential for improvement.

5 **Users’ awareness of the knowledge available may be insufficient** Even though those users who are clear that they are using research results are not usually academic research users. This means that they are often more interested in the content of the research rather than its origins. In other words, they may use the results without knowing that they are using them. The research groups who are known to the majority of users are research groups with whom they have had personal contact and who thus have helped the research results to be made known to the users, However it is not necessarily the case that the research results that are spread are based on separate research and this is not important to the users. Dialogues with users can therefore only provide a limited impression of the research upon which their practice is based.

5 Academic collaboration

The research into police enforcement was, as described above, largely carried out in the form of co-operative projects particularly with researchers from VTI and from the consultancy company TOS AB. This collaboration also led to a number of joint publications and in general was an important factor in all work on traffic enforcement that took place in this period.

The researchers who took part in these projects came from different backgrounds and had differing degrees of focus on the research questions. For example the Uppsala group primarily concentrated on the question of subjective risk of detection and its effect on behaviour. TOS AB was involved with objective risk of detection and the researchers at VTI were very often practically oriented and worked more directly with the users.

Several of the researchers who took part in this collaboration emphasised that in this type of collaboration there will always be continuous reciprocal influences that make it difficult to say where the ideas come from. Some of the co-operating partners had a less academic approach to research practice and have therefore not written articles that give clear references to sources of inspiration.

The co-operating partners state that all the participants in this type of co-operation have played an important role and contributed to a greater *general* understanding of the effects of enforcement. They found that the field of behavioural research was a decisive form for background understanding for other research within the field, given that behavioural research may also have a causal explanation. This type of knowledge was defined as important in the development of research design and as such was a significant implicit factor in many studies that do not themselves consider behaviour. One of the co-operating partners for example showed that from time to time there are studies that clearly know nothing of this type of behavioural research and these are usually poor pieces of work. A degree of background knowledge within this field is also regarded as vital for more practical or scientifically oriented research.

6 The police enforcement input today

There are a number of statements from Rikspolisstyrelsen concerning traffic enforcement (such as RPSFS 2000:37, RPSFS 2000:39, RPSFS 2000:41, RPSFS 2000 42, RPSFS 2000:43, RPSFS 2003: 6, RPSFS 2004:8), but these deal exclusively with technical and legal details concerning the enforcement work, such as frequency of equipment inspections, training requirements and legal documentation requirements.

A new strategy document was also published in 2006 on traffic enforcement (Rikspolisstyrelsen, 2006a), and a national plan for police traffic safety work (Rikspolisstyrelsen 2006b). The strategy only refers to academic publications to a limited extent and then mostly to The Swedish Road Administration's home pages – but in general it gives a clear impression of a wish to be on safe, evidence-based ground. For example it states that "a series of reports indicates that there are great opportunities to develop the police's safety work". It also states that

> *"Research has shown that police enforcement is socio-economically effective when it is carried out in the right way. The best results come from speed enforcement, drink driving enforcement and seat belt enforcement. High levels of enforcement and reporting, especially when* ***compliance with the legislation is low****, affect traffic safety in a positive way, Traffic safety researchers estimate that for every 100,000 drink driving checks the lives of four people are saved in traffic."*

In spite of the lack of direct references, the strategy nonetheless gives the impression of being based on research, both with regard to the benefit of enforcement as a whole. And with regard to the type of enforcement that is most desirable.

The strategy also underlines that the task of the traffic police in relation to Vision Zero is to prevent accidents by stopping dangerous situations from arising, as well as contributing to better adherence to the legislation through enforcement. There are four prioritised areas for enforcement: "speed", "drink driving" "safety equipment" and "aggressive driving", of which the last is new in this strategy.

The national action plan goes into greater detail about how the strategy should be followed up in 2006, including in the form of concrete measures within each of the prioritised enforcement areas. The goals that are particularly relevant in this context are the goals for speed enforcement and drink driving. These are:

- The average speed on accident black spot roads should go down
- Speed enforcement must be well-planned and easy to advertise in order to achieve the best effects.
- The reporting limit for speeding should be lowered. This means that speeding in excess of 6 km/hr above the limit must be reported.
- The number of reports should increase, mostly by issuing fines

- The police should carry out two million breathalyser tests (...) The test campaign must be well-planned and easy to advertise in order to achieve the best effects.
- In order to carry out the number of checks that are required in appendix 1, breathalyser tests should be carried out in normal circumstances as part of the police work, when encountering a driver in a traffic situation.

Much of this can be traced back directly or indirectly to research into police enforcement, see section 1. Interviews with former and current Swedish traffic police confirmed that the national enforcement strategy was regarded as being based on and informed by research. However a number felt that there could be a huge gap between these strategies and what actually happens at the local level. In some areas, clever leaders will ensure that the strategy is adapted, while in other places it may be difficult to implement the strategy locally in a meaningful way. In particular, it was noted that the goal to increase the number of reports could contribute to removing the focus from local traffic problems

7 Reduction in police training

In Sweden, fundamental police training is offered at three different places: at Polishögskolan (The Police Training College) in Sörentorp, at the University of Växjö, and at the University of Umeå. In order to become a *traffic police officer*, further education lasting a minimum of two years is also required.

Training in traffic safety work is part of the fundamental police training. In the study handbook for Polishögskolan 2006/07 it states that the students shall acquire “in-depth knowledge and understanding of the aims, functions and development of national traffic safety” and they that should have the “ability to convert the main aim of traffic safety into a knowledge based and problem-oriented traffic enforcement.”

In practice, however, traffic enforcement is not a major part of the curriculum and the different educational establishments say that the use of research results in teaching is relatively limited. Students are required to learn how to enforce traffic measures with a view – in the new strategy- towards preventing high speeds, drink driving, inadequate use of safety equipment and aggressive driving. Given that this form of education is largely concrete and tangible, research literature is seldom used with the students, but several of the institutions state that the knowledge that is transmitted is still seen as research-based, given that it is based on the national strategy and that everything possible must be done to get across the message that enforcement is an effective traffic safety measure. Some of this is to be found in the curriculum literature, but the level of detail within these areas will probably vary between the different teaching establishments. At one, it was emphasised that attempts were made to use the same - updated – information that the authorities use, and that thus students are being taught to think effectively in relation to enforcement, and to focus on problem-based work. This means, amongst other things, that students are aware that traffic enforcement should be directed at problem areas (whether these are identified through statistics or via complaints from the public), and that students know how to look at problem areas, in both the short term and the long term.

In addition, police training also involves external lecturers for these subject areas, particularly representatives from VTI who come to talk about the best possible forms of enforcement. Representatives from The Swedish Road Administration have also contributed in this context.

Further education for “traffic police” involves traffic enforcement to a greater degree. The aim of the first compulsory further education course in traffic enforcement at Polishögskolan is described thus:

”After the course, participants shall:

- Understand and be able to apply problem-oriented situations in local police work or traffic police work
- Have general basis knowledge of the political aims for traffic safety and traffic safety research within the road transport system
- Have fundamental knowledge about how traffic safety work is carried out, the different roles of the authorities and forms of co-operation
- Have extended knowledge of the area of traffic law”

Even though it is one of a number of subject areas, it can be seen that knowledge of traffic safety research is part of what traffic police students are required to study. Given that a significant part of the expertise required is a good knowledge of the Rikspolisens enforcement strategy, this will also determine the course content to some extent.

At Polishögskolan a new five-point course is currently being developed for leaders within traffic safety work. This course will particularly focus on making the traffic police work “evidence based”, and covers strategic analysis and how the enforcement should be set up. The aim of the course is analysis panning and follow up with the intention of creating problem oriented, evidence based planning and work within traffic enforcement. The focus will include how to find the available research-based information, the political framework, and questions around Vision Zero.

Even though the results of this course are clearly not yet known, it may be interesting to note that the very existence of an improved course for leaders within the field has been demanded by users (see later section)

8 Probable effects of the research

In the two sections above, we have gone through the official, documented state of police enforcement of traffic in Sweden today. To some extent it is easy to see effects of research into enforcement here. Some of the most visible and obvious examples are:

- That police enforcement is actually research-based, or that it is at least seen as a goal. This has taken place over the last 15 years.
- General consensus that police enforcement is an effective traffic safety measure. This is one of the most significant elements to which the combined research into police enforcement has contributed. This is expressed, for example, in the statement that enforcement is socio-economically profitable.
- The assumption that increased enforcement leads to improved adherence to the legislation. (Demonstrated in TFD, 1983, Nilsson and Åberg, 1986, Åberg and Haglund, 1989 amongst others).
- The focus on accident black spots (as emphasised in Nilsson & Åberg, 1986).
- Systematic, planned implementation of enforcement for best effects. This implies that differences in effect have been demonstrated for various forms of enforcement.
- Reduced reporting boundary for speeding. (Studied in Nilsson, Andersson, Haglund and Åberg, in VTI's series)
- Increased number of breathalyser tests. Again this shows the significance of the risk of detection on following the rules.

These points from the national strategy and action plan will also be reflected in both the fundamental training and further education for the police. The role that the research results play will vary between the different teaching establishments and also in relation to who is doing the teaching. If the strategy education for traffic police is a success, it is likely that research results will be used better and more in the future.

If we look below the national level, and look at how police enforcement is set up in practice, the picture is somewhat less clear. Given that the police force in Sweden is decentralised, and each district police chief operates independently, there are major differences between the police districts. The national strategy programme and action plan are intended to create unified and effective enforcement, but there are no direct, central steering directives on how this enforcement should be set up to be most effective. This is up to each head of traffic police who will set up the strategy for his own district.

This indicates that in some police districts research results are being used actively and continuously to promote the most effective enforcement possible, while in other areas the results are almost unknown. Some of our contacts were connected with highly active police districts, where they say that the research is being used actively. However, the research used here is regarded as untapped potential for other police districts. Amongst the insights gained from the research, the following were identified:

- Planning is being done in relation to the risk level on different roads and enforcement is being carried out at places where the risk is highest (for example roads with a 90 km/hour speed limit and no dividing barrier).
- Drink driving checks are often carried out near off-licences or ferries or at special events. This means that the alcohol abuser perspective is included.
- Distinguishing between preventative enforcement, where the aim is to be seen by as many people as possible, and repressive enforcement, which is targeted at specific goals, such as specific stretches of road or specific individuals.
- The research has also led to a better understanding of the consequences of high speeds.
- The observation that measures must be directed at commuters. The police have themselves experienced the difference between carrying out enforcement on commuter routes and on roads with mixed traffic – it appears that the results are much worse on roads that are not commuter routes, but the accident figures improve considerably when the same enforcement resources are used on commuter roads.
- Manual enforcement cannot compete with automatic traffic enforcement, which results in fewer injuries and is more cost-effective.
- The frequency of enforcement is justified by research. This applies to drink driving enforcement, seat belt enforcement and speed enforcement that are based entirely on the documented effects of enforcement and how this leads to a reduction in injuries.
- The importance of working systematically in order to see the effects of enforcement, and to compare results in the period before the enforcement with measurements taken at different times after the enforcement. The experiences accord with the researchers conclusions, namely that there are few long-term effects of enforcement, the effects are highest around 14 days after the end of the enforcement period. This has also been used as an argument for introducing ATK. Given that frequent enforcement works when it is directed at the right target group, it has been much easier to bring in ATK as a supplement to traditional enforcement.

ATK with the ”Swedish model” that uses numerous cameras and covers large stretches of roads creates a much greater risk of detection and hence has much greater effects on road users behaviour.
- Research that shows for example that car drivers quickly find out and tell others where the enforcement is taking place, how long it will last, what the police are enforcing and what the tolerance boundaries are.
- Research into physical tolerance levels.
- Research into drink driving that shows that very many have dangerously high alcohol consumption.

As mentioned, effects can be unclear and difficult to determine unambiguously. A former co-operative partner stated that given that part of the research into traffic enforcement found that the objective risk of detection was imperceptibly small, and the research group at Uppsala found that there was a link between subjective and objective risk of detection, it is possible that these results led to a transition to greater use of drink driving enforcement, which often had greater effects because it was well covered by the media. Another player suggested that, perhaps partly due to the research results from Uppsala, there has been greater focus on taking away drivers licences than on raising fines, since the research indicated that the rise in fines would have to be extremely high to have any effect.

It was also noted more generally that given that this type of research has a strong theoretical element, it is possible that the behaviour model thinking has been developed through these research projects.

However, other players felt that the group in Uppsala had been relatively anonymous in relation to the police and that the police had been more involved with the research groups at VTI and the University of Lund, that have carried out more concrete research projects and have been more active in their relationships with users. There are obviously also groups that to some extent have worked in co-operation with Uppsala, so the results may have come from a number of environments, and from a more combined Swedish research input.

9 Mechanisms that promote or hinder the benefits of research

In the interviews that were carried out in connection with this case study, it became clear that there are a number of points of view as to what is necessary for the police traffic safety work to have a practical effect. Some of these ideas may well be of such a local and specific in nature that it is difficult to generalise them to other fields but the majority of phenomena will probably be recognised within other subject areas and organisations. Below, these points of view have been divided into four broad categories according to where in the knowledge chain the mechanisms or obstacles are located. It should be noted, however, that there may be some overlap between the different categories as we are not dealing with four completely independent variables.

9.1 The design of the research

a The research question

Many of the contacts highlighted the significance of the research being designed in such a way that it could also be used outside the research environments. For example it was noted that Kommitteen för Övervakning och Påföljd functioned very well because it created opportunities for close, lasting co-operation between researchers and users. Through this committee it was possible for the representatives for the Rikspolisstyrelsen to state the kind of research that was required in the organisation and for the researchers to design projects in collaboration with the user group. Generally it was noted that the focus needs to be on the questions that are central for the user groups. Similarly others noted that the police often had difficulty in using research results, precisely because they had not funded the research and were not involved in the process.

b Research communication

It was mentioned that it cannot be taken for granted that the users will look for results in the usual way. ”The results must therefore be presented well, with good summaries, good overheads and a generally persuasive presentation. It is important that the public can see opportunities for practical implementation of a theoretical insight. It must be possible to see how this can become concrete work, otherwise the research will just remain literature”.

9.2 The researchers’ relationship with the users

An important condition for this type of research is that it must be capable of being used effectively, and that it is communicated to the users. A significant part of this communication happens via the formal channels discussed above (strategies and training) but these can both be of a very general nature and thus communication is required at a higher level,

Here the police are in a somewhat different class to other traffic safety workers, in that those working with traffic safety in the organisation often have some research background and thus have a professional attitude to the research results, and also both the network and the expertise that are necessary to keep up to date with research developments.

On the other hand, within the police force the use of professional channels such as academic publications is relatively limited, even by those who deliver the training. The use of Swedish research reports and periodicals issued by the Swedish authorities within the field, such as VTI-Nytt, is more widespread.

What people describe as sources of information depends on their position in the system, experiences, networks and interests. While some of the police users had a strong personal interest in the field and hence actively looked up researchers, research institutions and results (and for example always read research reports from the major institutions) others had a more passive attitude to the field and only acquired information that was explicitly directed at them (through lectures for example).

a Adapted dissemination of research
- Researchers exposure
  Not all the police read about research or go to conferences. It is therefore emphasised that the researchers themselves need to try to reach the police, for example through meetings and conferences
- Popular science displays
  A number of contacts wanted research to be “visible and readable”, and understandable for a public made up of laymen. This means, for example, clarifying what is new knowledge, and its potential applications, ideally through an alternative research report that is written explicitly for users and is based on their situations.

b Long-lasting personal contact

A conspicuous trend is that personal contact with the research institutions appears to be highly significant for developing knowledge about research. A personal relationship to the researchers apparently made it easier to keep updated with what is going on in the field and possibly also to make use of the findings, as it is possible to discuss them with the researchers themselves.

Many of the police described VTI as an important organisation, where there was close co-operation. VTI has been highly visible in the field both as an organisation and through individuals, for example through lectures, courses and taking part in meetings. Even more important is the long-lasting research co-operation that meant that “results were not just sent out on paper”. Personal relations with those responsible also meant that good co-operative routines were set up, and thus the research was carried out in a better way (for example high rate of response). However it takes time to build up relationships based on trust.

The Swedish Road Administration was also described as important by many, both as a co-operating partner and as a source of information about research. A third institution that was noted was the University of Lund.

9.3 Organisational phenomena within the police

a Spread of information/learning

Many contacts noted that even though the research has an effect on Rikspolisstyrelsen, the results are not necessarily known at all levels within the organisations.

- In order for the knowledge to be disseminated, some felt that there was a need for an ”improved and on-going further education for the police”. This appears to have worked relatively well in the two most northerly counties, even though more frequent communication is still desirable.

b Inertia/conservatism

- Some of the contacts, both researchers and the police, say that it is difficult to get the police to make use of the research results, even when they are concrete, robust and formulated for relevant players. Many of the users are said to use their own experience over and above research results. In addition the use of research results will often require adaptation which leads to more work.
- A related problem is the lack of openness with regard to research results that may also be connected to the fact that people are not used to this type of material and therefore have difficulty in finding their way around this field. Wishes were expressed to create ”hybrids” with one foot in the world of research and the other in the police force. This could be done through the new leader training, described above, or through police PhD students working on questions of traffic safety.

c Organisation/hierarchy

- Several contacts noted that the police force is strongly hierarchical and that changes in the fundamental education will therefore have little effect. There is a high dependency on individuals who are in the right place and on their level of involvement.
- It was also noted that it is difficult to achieve changes in traffic police in general and that improved leadership training may well be important in spreading knowledge down through the system The way this form of education and further education works now means that the subordinates undertake further education and acquire the information, and not the leaders
- With regard to greater mobility within the organisation, the transfer of knowledge may suffer. To a large extent, people no longer build up expertise over time. It was also noted that the time available to read research results has also been reduced.

- The drastic reduction in the number of traffic police means that the involvement in traffic safety questions may be less, which means that it is less likely that people will look up the research results.

9.4 Political and societal conditions

Some of the known research results are also not taken into use because they do not make a political impact for various reasons. For example the fact that it is not compulsory to use a cycle helmet is one such case. The two factors identified here were:

a Lack of knowledge in the political system
It was noted that, in line with other users, politicians often lack knowledge about traffic safety, and also lack opportunities to make use of the research that is available. They often simply do not have the time to go into these questions in depth. One contact stated that this also goes together with the way in which the research results are presented and that measures should be presented through a documented impact analysis, also at the local political level.

b Lack of acceptance amongst the population
Some measures are not implemented because the political authorities do not want to promote measures that will meet with great resistance amongst the population, such as reducing the speed limit.

10 The benefit of police enforcement

The effects of traffic safety research will ultimately consist of a reduction in the numbers killed and injured in traffic, or a reduction in the risk level in the traffic system. It is difficult to draw precise causal directions in this field but Elvik (2005) considers a significant traffic safety benefit from effective police enforcement is likely.

From 1981 to 2004 the number of enforcement carried out in Sweden increased significantly (Brüde 2005). The number of drivers checked per million vehicle kilometres is a measure of the risk of detection for traffic offences. An analysis of the data for the period 1981-2004 indicates that the risk of detection has increased. It can be estimated that this had led to a reduction in the numbers killed of around 150 people annually.

As such, this is the single measure that according to Elvik (2005) has had the greatest injury reducing effects of all the measures covered in this document.

It is difficult to stipulate the monetary costs of this effective enforcement: to the extent that there is talk of a real effectiveness the cost is almost non-existent but where there is talk of the amount of enforcement, there is obviously a cost in the form of personal resources (or any technical equipment). Nonetheless it can probably be assumed that the effective enforcement is amongst the more reasonably accessible traffic safety measures in Sweden.

As noted in the Rikspolisstyrelsens national strategy for traffic enforcement, there are still major differences between the various police districts with regard to effective enforcement, which indicates that there is still significant potential for this measure.

Obviously it cannot be maintained that there is a direct connection between the research at Uppsala and the increase in safety, Nonetheless, it is probable that the research together with related research carried out at the same time and often in co-operation has made a significant contribution to understanding police enforcement as a traffic safety measure. Thee most fundamental insights are also significant: namely that subjective and objective risk of detection co-vary to a relatively high degree and that increased subjective risk detection leads to lower speed and reduced accident figures. Another notable insight is apparently the more systematic planning related approach to enforcement which has led to choosing stretches of roads, times and target groups with greater care.

11 Summary

Results from the effects analysis can be summarised as follows:

- The case study demonstrates how fundamental and inter-disciplinary knowledge of a field are requirements for running effective traffic safety work.
- Police enforcement is one of the most cost-effective measures in traffic safety work
- Knowledge that a visible police force and police enforcement have injury- reducing effects has been established by Swedish researchers amongst others
- Knowledge about the relationship between subjective and objective risk detection is decisive for the design of enforcement strategies
- The research was initiated through a TFD-research programme.

- Research results are best disseminated to the police through long-term co-operation, and also through personal relationships, seminars, conferences and lectures.
- The police force’s lack of expertise within research-based work may be an obstacle to more use or earlier use of the research results.

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Appendix A: Interviews

This document is largely based on information obtained by telephone or email from:

Name	Title/area of responsibility
Uppsala University, Department of Psychology	
Lars Åberg	Professor (20 % Uppsala University, 80 % Högskolan i Dalarna)
The Swedish National Road and Transport Research Institute VTI	
Göran Nilsson	Former head of research at VTI
Nationalföreningen för Trafiksäkerhetens Främjande	
Gunnar Carlson	Former head of traffic safety at NTF and head of research at VTI
Nils Petter Gregersen	Professor, former researcher at VTI, now head of traffic safety at NTF
Police	
Sten Byström, Rikspolisen	Worked with traffic safety and ATK
Rune Petterson	Former head of the police in Umeå
Gunnar Andersson	Former researcher at VTI
Nils Göran Strömberg	Responsible for traffic, police training, Växjö University
Håkan Jaldung	Former head of the police in Göteborg; formerly in Rikspolisstyrelsen
Håkan Fuhrman	Police lecturer and responsible for further education, police training, Umeå University
Magnus Westergren	Polishögskolan
Per-Ove Nordquist	Polishögskolan
Others	
Ernst Nilsson	OECD, formerly TOS-AB

Appendix B: List of research projects on police enforcement at the Department of Psychology, Uppsala University

We have assumed that the following projects from VINNOVA's database have been funded as part of the research into police enforcement. Projects in bold are evaluations, projects marked with an asterisk * were carried out in co-operation with TOS AB, so that it cannot be assumed that the all the projects were part of the Uppsala group, the year indicates the year the project started. *Translator's note:* The projects are written in Swedish.

TFB/KFB	Effects av övervakning i tätortstrafik för BÅ 1984/85	1986	746 952
TFB/KFB	**Utvärdering av effectsna av höjda böter**	**1982**	**591 303**
TFB/KFB	**Utvärdering av den i Sweden införda 0,2 promille-gränsen i trafiken**	**1991**	**333 008**
TFB/KFB	Undersökning av måttet subjektiv upptäcktsrisk	1983	513 046
TFD	Undersökning av måttet subjektiv upptäcktsrisk	1984	401 429
TFB/KFB	Trafikonykterhet och de trafikonyktra	1986	427 285
TFD	Övervakningsintensitet och subjektiv upptäcksrisk	1981	316 424
TFD	Trafikövervakning - riktlinjer för fortsatt FoU	1980	168 056
TFD	**Utvärdering av intensifierad övervakning med utandningsprov***	**1983**	**415 855**
TFD	**Utvärdering av effectsna av höjda hastighetsböter***	**1983**	**490 495**
TFD	Översikt rörande resultaten av TFD hittillsvarande FoU om övervakning	1983	85 304
TFB/KFB	Laglydiga och lagbrytare i trafiken	1983	998 087
TFB/KFB	Konsekvenser av hastighetsdämpning	1980	229 553
TFB/KFB	Stabilitet och generaliserbarhet i observerade beteenden	1986	1 064 741
TFB/KFB	Inventering av bilförares säkerhetsmarginaler	1986	1 060 622
TFB/KFB	Bilförares bromsreaktionstid	1988	791 754
TFB/KFB	Bilförares felhandlingar och automatiserat beteeende	1989	1 233 037
TFB/KFB	Samarbetsgrupp för forskare aktiva inom in the area trafikanter	1989	157 710
TFB/KFB	Subjektiva faktorers betydelse för förares val av hastighet	1990	1 236 496

TFB/KFB	Attityder och trafiksäkerhet. Litteraturgenomgång	1993	113 467
TFB/KFB	Utveckling av metod för att undersöka individuella beslutsmod. hos bilförare	1993	412 207
TFB/KFB	Utveckling av metoder för att studera faktorer som påverkas av förares val av avstånd mellan fordon	1993	466 358
TFB/KFB	Samarbetsgrupp för forskare inom in the area trafikanters beteende	1994	33 153
TFB/KFB	Utveckling av modeller för trafikanters beslutsfattande och beteende	1994	3 160 875
TFB/KFB	Modeller för förares beslutsfattande och beteende	1997	3 270 712
	Beteendevetenskapliga undersökningar	1979	1 618 954
TFD	Upplevd och verklig olycksrisk - utveckling av mätmetoder/ form och styrka hos sambandet	1980	831 082
TFD	Formella och informella trafikregler	1981	101 256
TFD	Hastighetsdämpningsprojektet. Konsekvenser av hastighetsdämpning på samspelet mellan trafikanter	1981	313 893
TFD	Förekomst av informella trafikregler	1982	418 354
TFD	Förares förmåga att värdera olycksrisk. Möjligheter till påverkan	1982	1 660 216
TFD	Undersökningar för att utveckla ett polariserat mötesljus	1975	88 117
TFD	Trafikanters informationsselektion. Metodutveckling och situationsmätning	1975	2 199 095
TFD	Trafikanters informationsinhämtning i kritiska situationer -	1978	1 953 654
TFD	Laglydiga och lagbrytare i trafiken	1984	195 819

Transportøkonomisk institutt
Stiftelsen Norsk senter for samferdselsforskning

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O-3165 Effect analysis of Swedish traffic safety research **APPENDIX 7**
Research leader, cand.psychol. Fridulv Sagberg

APPENDIX 7
Case study: Development and use of VTI’s driving simulator

Contents

1 Purpose and history

The research into the significance of driver behaviour for traffic safety has in recent years moved more and more in the direction of **direct studies of driver behaviour** (as opposed to indirect studies such as self reporting by drivers etc.)**.** This reflect a stronger focus on the role that the direct interaction between road users, road and vehicles plays for traffic safety, in relation to the significance of background factors for drivers, which can be found in other ways (for example, via questionnaires and statistics). This development can also be related to the fact that the research within this area is of a generally high level and that the technology has enabled more advanced research methods for registering behaviour, using driving simulators and instrumented vehicles.

1.1 Long history of traffic safety research

The use of driving simulators of various types has a long history in traffic safety research, first and foremost as a tool for studying driver behaviour and the factors that affect this behaviour, with regard to the road, the vehicle and the drivers themselves. In other words the aim is to obtain a better understanding of the psychological basis for safer driving. Then main reason is that by using simulators it is possible to test the effects of various influencing factors that it would be difficult or expensive to test in real traffic. For example a modern simulator will be able to simulate different ways of designing the road system with regard to road geometry, signs and road markings which would be almost impossible to do on a large scale by building test roads for testing with real traffic. Hence simulation provides a basis for choosing solutions that can later be tested in field studies on actual roads. By manipulating the traffic conditions (simulating other road users' behaviour) it is possible to test behaviour under conditions that occur very seldom in real traffic, but which are serious when they do first occur; in this way knowledge can be obtained about drivers' abilities to master different types of critical traffic situations. With regard to the actual vehicles, the simulator makes it possible to test effects of equipment and modification that cannot be done on cars in normal traffic, for either legal or ethical reasons. The same applies to conditions affecting drivers, for example the use of legal or illegal drugs, alcohol or conditions such as tiredness or illness. Research using driving simulators can therefore be expected to provide knowledge about driver behaviour that can be used as a basis for implementing effective traffic safety measures.

According to Straus (2005)[1] the first driving simulators were developed before 1920, with the aim of testing the skills of drivers of public transport vehicles. During the following 40 years there was a development in the direction of ”mock-up” cars equipped so that they could test drivers reactions to different stimuli. Mechanical moveable scenes or films were used in some cases. During the 1960s it became common practice to use films to depict different road and traffic environments. Originally car manufacturers produced the first simulators, but research institutions, insurance companies and others have also developed simulators. Up until about 1970 simulators were rigid, so only visual information could be simulated and drivers reactions to different situations could be measured. Later simulators were placed on moveable platforms so that it was possible to simulate how the acceleration forces in longitudinal and horizontal directions affected the driver.

1.2 The driving simulator at VTI

The first driving simulator at VTI with a moveable platform was commissioned in the spring of 1983. Planning for the driving simulator had been going on since the 1960s and simpler simulators had been in use since 1978.

The simulator with a moveable platform was inspired by simulators that had been developed elsewhere, first and foremost Volkswagen’s simulator. The theoretical model for movement that the VTI simulators were based upon is described by Nordmark (1984).

The current simulator (”Driving Simulator III”) was taken into use in April 2004 and is the third in a line of simulators with moveable platforms. The basic principle has been the same for all three versions. The simulator consists of a car that is fixed to the moveable platform, and which acts like a normal car. The road and the traffic environment are shown on a large screen in front of (and partly to the sides of) the car. The screen is in a fixed position in relation to the car and moves with the car.

The car's movements in relation to the road and traffic are simulated through movements of the picture on the screen. The movements of the picture are steered by a computer linked to the car’s gears and steering. The system for simulating the road and traffic can be the same for a fixed simulator and for simulators with a moveable platform.

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[1] Straus, S.H., 2005. New, improved, comprehensive, and automated driver’s licence test and vision screening system. Report FHWA-AZ-04-559(1). Phoenix, AZ: Arizona Department of Transportation.

The point of the moveable platform is that as well as simulating the *visual* effect from the road and traffic, the simulator can be used to simulate the effect of acceleration and retardation forces on the driver (*proprioceptive information)*. For example, braking can be simulated by bending the whole platform forwards, and acceleration by bending it backwards. Because the picture of the road follows the movement the driver will scarcely notice that the platform is moving. The change in the gravitational force will be experienced as retardation (forwards) or acceleration (rearwards). The aim of simulating proprioceptively in addition to visual information is to make the driving experience in the simulator more realistic i.e. more like real-life driving.

The main part of the research in VTI's simulators has dealt with cars. However lorry cabs can also be put in the simulator, and comprehensive research has been carried out into safety for lorries, fist and foremost in collaboration with Volvo Technology Corporation.

2 Evaluation criteria

As a basis for evaluating the significance of the driving simulator within traffic safety research, we have used the following criteria.

- **International publications and doctoral theses**
- These included published articles in international journals with a” peer review”-system. The significance is evaluated on the amount of articles published on the basis of research in the driving simulator, and the extent to which these were referred to later. Doctoral theses based on studies using the simulator are also an important criterion.
- **Use of the driving simulator in international projects**
  International collaboration projects, primarily EU-funded projects, where the driving simulator has been used, are an indicator of its significance.
- **Collaboration with the car industry**
  The extent to which research using the driving simulator has been carried out in co-operation with the car industry with the aim of improving cars’ characteristics will be evaluated, together with the degree to which the results from this research have bee taken into use.
- **Co-operation with the authorities**
  The evaluation of the significance of the simulator considers the extent to which results from the research have been used by the road authorities as a basis for implementing safety measures.

- **Co-operation with other research institutions**
  One benefit of the simulator may be that other research institutions can carry out their projects by hiring the simulator, with the result that research co-operation is established between VTI and other research institutions.
- **Innovation and product development**
  It may also be the case that the simulator has had societal benefits in the form of innovations linked to the development work, e.g. that new technology or knowledge is developed that could be used commercially, whether this applies to using the simulator in other contexts (e.g. teaching and training) or completely different applications where elements of the same technology or knowledge are relevant. It may also be the case that the development and use of this type of simulator has had an effect of the use of driving simulators elsewhere. These types of benefits are only covered to a limited extent here.

3 Research themes that have been studied using the simulator

3.1 Broad area of application

A number of different problems within the field of traffic safety have been studied through experiments in the VTI simulator. Here is a list of subjects that are taken to cover the majority of the research in the simulator.

- effects of mental and visual loading on driver behaviour (including studies of the use of mobile phones)
- effects of different aspects of roads and traffic conditions (tunnels, road markings, winter driving, fog etc)
- effects of tiredness
- testing different information and driver support systems
- the significance of the driver’s own state of health on driving behaviour (health, medicines, age, incapacity)
- the car’s driving characteristics

In table 3.1 we have presented an overview of research themes and references to published articles from the research with the VTI simulator. The table also shows some of the co-operating partners as well as EU projects including simulator research. The overview is not necessarily complete, but nonetheless it is assumed to provide a sufficient basis for evaluating the significance of the simulator research at VTI.

Table 3.1. Summary of research themes that have been studied in VTI's driving simulator with references to published works, EU-projects and co-operating partners. Funding sources are shown using the following codes: 1-Research Council, 2-Public authority or organisation, 3-Industry, 4- the EU.

Research theme	References (international articles in bold)	No. of citations	Funding	EU-projects	Co-operating institution
State of health and use of medicines					
- sleeping pills	Laurell & Törnros, 1984				Various hospitals in Stockholm and Linköping.
	Laurell & Törnros, 1986	12			
	Törnros & Laurell, 1990	5			
	Törnros et al., 1998a; b		2		Karolinska hospital., Ear, Nose and Throat department.
- sleep apnoea	Haraldsson et al., 1990	34			
(effects of operation)	Haraldsson et al., 1991	21			
	Haraldsson et al., 1995	18			
- visual problems	Törnros, 1986				Karolinska hospital, Ophthalmology Department
	Lövsund et al., 1987				
	Løvsund et al., 1991	12			Chalmers.
- benzodiazepine	Törnros et al., 2001	?			
- anti-inflammatory medicines	Laurell & Törnros, 1987				
Use of mobile phones when driving	Alm & Nilsson, 1991		1,2,4	BERTIE	
	Nilsson & Alm, 1991		1,2,4	"	
	Alm & Nilsson, 1994	53			
	Alm & Nilsson, 1995	62			
	Alm & Nilsson, 2001	4			
	Kircher et al., 2004		2		
	Nilsson et al., 2005				
	Törnros & Bolling, 2005	0			
	Törnros & Bolling, 2006	0			
Tiredness and physical exertion	Törnros & Laurell, 1987		2		
	Törnros, 1989				Karolinska institutet, Institute for Psycho-social Medicine.
	Kircher et al., 2002		3		
	Åkerstedt et al., 2005	6			
	Ingre et al., 2006a	0			
	Ingre et al., 2006b	0			
Mental (cognitive) and visual loading, distractions	Harms, 1990, 1991a,b		1		
	Harms, 1992	?			
	Nilsson et al., 1998		2		
	Falkmer et al.., 2000		1		
	Almén, 2001, 2002				
	Östlund et al., 2006		1,2,4	HASTE	
Alcohol and drugs	Laurell & Törnros, 1986,1987				
	Törnros & Laurell, 1987				
	Laurell & Törnros, 1991	?			
	Törnros & Laurell, 1991	?			
	Björkman, 2005				
			2		
Road design:					
- Tunnels	Törnros, 1996				
	Törnros, 1998				
	Törnros, 2000	10	2		
- Rumble strips	Anund et al., 2005				
			2,4	SENSATION	
- Winter driving	Wallman, 1997, 1998				
			1		
- Mid field	Vaa & Ulleberg, 2006				
			2		TØI, Oslo
- Fog	Harms, 1993				
	Nilsson & Alm, 1996				
- Overheight	Helmers & Törnros, 2004		3		

Research theme	References (international articles in bold)	No. of citations	Funding	EU-projects	Co-operating institution
- Ridged road surfaces	Törnros & Wallman, 2003		1		
	Harms, 1997		2		
- Driving lane signals					
	Helmers & Törnros, 2006		2		
- Transition curves					
Stress (infrasound, noise, heat	Nilsson et al., 1988		1,3		Working Environ-ment Institute at Umeå
	Morén et al., 1989		1,3		
Driver training	Nalmpantis et al., 2005		2,4	TRAINER	
Traffic control	Bolling, 2004		2,4	FORMAT	
Disabled drivers	Peters & Nilsson, 1994		1,4	TELAID	
	Peters, 1999				
	Peters & Østlund, 2005		2		
Older drivers (validation)	Hakamies-Blomqvist et al., 2000		1		
Vehicle technology					
Anti-collision system	Janssen & Nilsson, 1992		2,4	GIDS	
	Nilsson et al., 1992				
	Törnros & Harms, 1999		2,4	IN-ARTE	
	Nilsson & Peters, 1998,1999			AC-ASSIST	
- Adaptive speed retention	Hjälmdal & Torslund, 2006				
	Nilsson, 1996		2,4	AIDE	
	Nilsson & Nåbo, 1996		1,2,3		Saab Automobile
	Oskarsson, 1999		4	EMMIS	Saab Automobile
	Törnros et al, 2002				Linköping University
	Engström et al., 2005			ADVISORS	Volvo Technology Corporation
- Information systems	**Alm & Nilsson, 2000**	1	2,4	HASTE	
- "Incident warning"	Harms & Törnros, 2004	?		HOPES	
- Automatic braking					
- "Driver monitoring"	Peters & van Winsum, 1998, 1999			SAVE	
	Nordmark et al., 1999				
- ITS in general	Bertollini & Hogan, 1999		2,4	IN-SAFETY	
- ABS-brakes	Aurell et al., 2000				
- driving characteristics	Pettersson et al, 2006				
- lorries					
- " -					
General overviews of simulator-based research and opportunities; method development; validation	Nordmark et al., 1986				
	Törnros et al., 1988				
	Nilsson., 1989		1,2,4	BERTIE	
	Nordmark, 1994				
	Nilsson, 1993a,b, 2005				
	Harms et al., 1996			GEM	
	Törnros et al., 1997			- " -	
	Björkman, 2003				

3.2 Development of methodology – the question of validity

Since research using driving simulators is designed to provide knowledge of driver behaviour in real traffic, it is reasonable to ask about the external validity of the results from the research, i.e. the extent to which the results can be generalised for real traffic. There is no simple answer as to whether the results from driving simulators are valid or not. This depends on the problems being studied, and some studies will have good validity, while others may be less good. Also it is not necessarily the case that a realistic driving experience (”high fidelity”) is necessary for the results to be valid. Some studies may well be studied with equally high validity in a simple simulator. In some studies, other elements may affect the validity, for example, if the driver’s attitude to risk is decisive for his behaviour, then the awareness that driving off the road in the simulator is not dangerous will mean the driver takes more chances than he would in a similar situation in real life. It is therefore important that validation studies are carried out where behaviour in the simulator is compared with behaviour when actually driving in order to chart the factors that affect the simulator’s validity.

Actual practical applications of driving simulators include testing drivers’ skills in connection with driving tests or other evaluations of individual drivers, and as a training tool in driver training. It should be noted that these applications are linked to special validation problems. As a rule, the simpler simulators are used for these purposes, while research in an advanced simulator can provide important knowledge for validating practical applications of simulators for training and testing.

4 Publishing work carried out in driving simulators

The scope of both international articles from studies in VTI’s driving simulator and more recent research that has referred to this, indicate a high degree of awareness of the traffic safety research that is carried out using VTI’s driving simulator. There are also numerous reports in other publications and other documents such as papers.

4.1 A quarter of VTI’s articles

We have registered 21 international articles based on traffic safety related research in VTI's driving simulator that were published between 1986-2006. In this overview, we have only included articles in journals that involve a ”peer review” of articles. There are two main areas where there have been a high number of publications, namely effects of the state of health and medication on driver behaviour, and effects of the use of mobile phones while driving.

With regard to health and medication, in the period from 1986-95, 7 articles were published plus one in 2001, and for use of mobile phones, 5 articles were published between 1994-2006. Two articles were published on the effects of alcohol

A further 3 articles dealt with tiredness and falling asleep, two on visual and mental loading and one validation study that compared simulated and real driving in tunnels, (the Ekeberg tunnel in Oslo).

In its self-evaluation VTI listed 82 publications, some of which are not related to traffic safety. As we have found at least 21 articles based on studies in the driving simulator, we can assume that these comprise at least one quarter of all the international articles on traffic safety at VTI.

We note that for some themes, where several studies have been carried out in the simulator, no articles have been published in international journals. These involve disabled and elderly drivers, as well as vehicle technology and ITS. With regard to the effects of road and traffic conditions, where a number of studies have been carried out, only one article has been published.

4.2 Citations of published articles

Some of the published articles are referred to in a significant number of later works. The first two articles by Alm and Nilsson (1994; 1995) on effects of mobile phone usage and driving behaviour appeared at the start of a period when the use of mobile phones increased strongly and where this subject aroused great interest within traffic safety research. These studies showed clear negative effects of the use of mobile phones, including reaction times, and this also applies to the use of hands-free phones. Due to the clear results based on methodologically sound experiments and practical relevance, these articles have been cited frequently, in 53 and 62 later works respectively (according to statistics from ISI Institute of Scientific Information).

A number of the articles on state of health have also been cited, with 34, 21 and 17 citations respectively for the three articles by Haraldsson et al. (1990, 1991, 1995).

Six of the published articles were published in 2005 and 2006. It is too early to evaluate the effects of this recent research, given that that it can take up to a year from the submission of an article to its publication (and sometimes longer). The fact that one of the articles from 2005 on tiredness has already been referred to 6 times indicates great interest in simulator studies in this field.

4.3 Dissertations- doctoral theses

A number of PhDs have been completed in traffic safety involving tests using the simulator:

- Lisbeth Harms: ”Studier av kognitiv belastning i trafikken” (Copenhagen University, 1992)
- Jan Törnros: ”Hangover effects of alcohol and carry-over effects of certain Benzodiazepine hypnotics on driver performance” (Uppsala University, 2000).
- Bjørn Peters: ”Evaluation of adapted passenger cars for drivers with physical disabilities” (Linköping University, 2004).

At present one PhD student is studying tiredness amongst drivers. There are also a number of dissertations and student projects.

4.4 Projects reported in the form of VTI publications

Going through VTI's publications series (”VTI rapport”, ”VTI meddelande”, ”VTI notat” and ”VTI særtrykk”) as well as other available sources shows that in addition to the international articles described above, there are at least 70 publications that are based on research in driving simulators (see table 10.1).

Some of these are ”papers” presented at international conferences, so that the international scope of publication is somewhat more extensive than would appear from the overview of the journal articles given above. In addition to the subjects covered in the international articles, the other publications cover areas such as road design, vehicle design and ITS as wells as testing special adaptations for cars for disabled drivers etc.

4.5 Methodology and validation studies

A significant group of publications are method-based works that describe the simulator's abilities as a research tool and also give as partial overview of typical research themes and problems that have been studied or could be studied using the simulator. A number of the studies that were carried out under the various subject themes also have a methodological basis. For example there are several validation studies such as the study of driving in tunnels (Törnros, 1996; 1998) which is a comparison of speeding and other driver behaviour when driving in a real tunnel and in a similar version of the same tunnel. The study of older drivers (Hakamies-Blomqvist et al., 2000) is also a validation study, where a comparison is made between driver behaviour in the simulator and driving on similar roads in reality. These validation studies form an important basis for evaluating the generalisability of the research that is done using the simulator in general and therefore has a benefit value for traffic safety research which is done using driving simulators elsewhere and in other subject areas.

5 The driving simulator as a key to participation in EU-projects

A significant part of the research with VTI's driving simulator has been carried out as a part of projects that come under the EU's framework programmes. The fact that these projects usually involve a significant number of parties from many countries means that a significant number of research institutions and users have gained direct access to the research results. Here we will list some of the EU projects that have involved research using the VTI simulator.

Under the EU's DRIVE research programme at the end of the 1980s, VTI took part in the BERTIE project on ”Changes in Driver Behaviour Due to the Introduction of RTI Systems” with simulator studies of effects of mobile phone usage on driver behaviour (Nilsson, 1989; Alm and Nilsson, 1991; Nilsson and Alm, 1991). A second project under the same programme which also involved studies using the VTI simulator, was GIDS ”Generic Intelligent Driver Support Systems” (Nilsson et al. 1992; Janssen and Nilsson, 1992).

DRIVE II included the following projects: ARIADNE ”Application of Real-time Intelligent Aid for Driving and Navigation Enhancement”, TELAID ”Telematic Applications for Drivers with Special Needs” with simulator studies of special adaptations of cars for disabled drivers (Peters and Nilsson, 1994), EMMIS ”Evaluation of Man-Machine Interface by Simulation Techniques” (Nilsson and Nåbo, 1996), GEM “Generic Evaluation Methodologies for Integrated Driver Support” (Harms, Törnrös and Alm, 1996; Törnros, Harms and Alm, 1997) and HOPES “Horizontal Project for Evaluation of Safety” (Alm and Nilsson, 2000).

Under the 4th. framework programme, VTI carried out a simulator study as part of the IN-ARTE project: ”Integration of Navigation and Anticollision for Rural Traffic Environments” (Törnros and Harms, 1999). The simulator was also used in the projects SAVE “System for Effective Assessment of the Driver State and Vehicle Control in Emergency Situations” (Peters and van Winsum, 1998; 1999) and AC-ASSIST “Anti-Collision Autonomous Support and safety Intervention System (Nilsson and Peters, 1998; 1999).

In the 5th framework programme, the VTI simulator was used in the project HASTE ”Human Machine Interface and the Safety of Traffic in Europe” (Östlund et al., 2006; Engström et al., 2005), in co-operation with. Volvo Technology Corporation amongst others. It was also used in the project TRAINER (Nalmpantis et al., 2005), where a simpler simulator was developed for driver training; the VTI simulator was used in an experiment to measure the effect of training in the TRAINER- simulator for driver skills. Other projects in the 5th framework programme where the simulator was used, were ADVISORS “Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety” (Törnros, Nilsson, Östlund and Kircher, 2002), FORMAT **“**Fully Optimised Road Maintenance”. (Bolling, 2004). VERT “Vehicle Road Tyre Interaction: Full Integrated and Physical Model for Handling Behaviour Prediction in Potentially Dangerous Situations”, and AWAKE “System for Effective Assessment of Driver Vigilance and Warning According to Traffic Risk Estimation”

In the EU’s 6th. framework programme a number of projects are underway where VTI is taking part with simulator studies. SENSATION ”Advanced Sensor Development for Attention, Stress, Vigilance and Sleep/Wakefulness Monitoring” (Anund et al., 2005) is intended to develop systems to detect tiredness and reduced vigilance amongst car drivers. The project IN-SAFETY ”Infrastructure and safety” includes testing information systems in VTI’s driving simulator. Other on-going projects are AIDE “Adaptive Integrated Driver-vehicle Interface” (Hjälmdahl and Thorslund, 2006), VERTEC ”Vehicle, Road, Tyre and Electronic Control Systems Interaction: Increasing Vehicle Active Safety by Means of a Fully Integrated Model for Behaviour Prediction in Potentially Dangerous Situations”, INTRO “Intelligent Roads”, COOPERS “Co-operative Networks for Intelligent Road Safety”, and DRUID “Driving under the Influence of Drugs, Alcohol and Medicine”.

The simulator is also an important part of the shared infrastructure for research that is being set up within the HUMANIST ”Human Centred Design for Information Society Technologies” network.

In many EU-projects, the simulator is important for VTI’s participation. In other cases participation may be an indirect effect of the simulator, in that the technological and behavioural sciences expertise that has developed around the use of the simulator is important for the projects.

6 Benefits for industrial users and for society

GM (SAAB in Trollhättan) has benefited greatly and is a major user of VTI's driving simulator in Linköping. The driving simulator in Linköping is very advanced and allows sideways movements along the tracks as well as movements with the help of hydraulic cylinders. SAAB could not have built such an advanced simulator with its own funds in Sweden.

The benefits of working with VTI and VTI's knowledge are large and advantageous for GM (SAAB i Trollhättan). VTI's researchers have knowledge about how the simulator should be used to obtain the desired results. VTI recommends methods and test programmes to deal with the problems described by the client. VTI also evaluates the registered data from tests in the simulator. VTI's simulator and its convenient location in Sweden means that the development of expertise is greater than if similar studies were to be carried out in Detroit or Germany. VTI's simulator contributes to good co-operation and contacts with Chalmers, KTH, LiTH and VTI. VTI has a group of people who do not suffer from motion sickness and hence are suitable for tests and trials using the simulator.

A large part of the research is done openly and in collaboration with competing car manufacturers such as Volvo. This type of research area provides validity for simulator tests. Test-driving in real traffic environments may be necessary in some cases and cannot be replaced by tests in a driving simulator. Concept testing is cared out internally with trusted co-operating partners. Tests which include a high degree of risk can only be done in a simulator and not in real traffic.

GM (SAAB in Trollhättan) has carried out, participates in and implements projects with the following content and questions:

- IVSS (In Vehicle Safety Systems) where the Swedish The Swedish Road Administration is a sponsor
- EMMI – cognitive stress that was an EU project in 1992 in co-operation with VTI amongst others
- Testing how adaptive speed restrictors should be designed as a development project for GM Europa
- What feedback information is required if drivers are to feel in control when driving? Examples of feedback information are steering wheel torque and reaction times to control steering (steering wheel impact, brakes, acceleration etc) by the driver. This is an internal GM study.
- Two PhD students (KTH) are studying the steering systems that are optimal for advanced car drivers (rally drivers) and standard car drivers respectively

GM (SAAB) is extremely satisfied with projects and research financed by VINNOVA and its predecessors and PFF. The application process and reporting are rational, short and non-bureaucratic. Projects with Swedish funding have been characterised by flexibility and good forms of co-operation. Projects within the Programme Council for Vehicle Research (PFF) are steered by industry's needs and wishes. Projects with Swedish funding are regarded as administratively simpler and more useful than EU-funded projects.

Volvo Car Corporation states that it has benefited from VTI's driving simulator in Linköping.

VINNOVA also funds work at other simulators. Volvo Technology has a simulator in Göteborg that is also used by Volvo Car Corporation. Volvo also uses Fords simulator in Detroit. The proximity of driving simulators in Linköping and Sweden leads to co-operation and a high degree of expertise within Swedish industry. Public funding via VINNOVA is a necessary catalyst for fundamental research and new projects. This is when the current programmes make new state funding necessary in order for Swedish industrial development to be able to maintain its high level of expertise and its position in Ford and GM respectively.

All driving simulators have limitations compared to testing in real traffic and it is important to have expert knowledge about what can be studied using different types of simulator. General expertise about simulators and analysis methods forms an important contribution from VTI.

Collaboration between Chalmers and Volvo Car Corporation helps to find methods for testing and evaluating the new systems which are coming into play in the field of active safety. Hans En, an associate professor partly employed by VTI and who has a 20% post at Chalmers, is a link person who has contributed to increased understanding of cognitive problem situations. A special road intersection at Hisingen in Göteborg is used in simulator tests with cognitive problem situations.

A large part of the research is done openly and in collaboration with competing car manufacturers such as Volvo. This type of research area provides validity for simulator tests. Volvo is very satisfied with projects and research funded by VINNOVA and its predecessors. The application process and reporting are rational, short and non-bureaucratic. Projects with Swedish funding have been characterised by flexibility and good forms of co-operation. Projects within the Programme Council for Vehicle Research (PFF) are steered by industry's needs and wishes. Projects with Swedish funding are regarded as administratively simpler and more useful than

EU-funded projects. Volvo's interest and participation in EU projects in the field of safety are increasing.

The most important benefit of state funding is that it creates co-operation between research and industry and the state acts as a catalyst for this process. The research leads to better fundamental higher education. FFP and the agreement on co-operation is a driving force in itself. The agreement means that industry is putting money into research State funding is a driving force and a condition for Volvo's focus within FFP and IVSS.

Volvo Technology which develops and manufactures heavy vehicles, is the industrial player that probably uses the VTI driving simulator the most.

For society, driving simulators have indirect benefits through the development of safer vehicles and because the interaction between people and vehicles is adapted to human capabilities and capacity. In addition, different solutions for major traffic and tunnel projects can be simulated so that traffic safety solutions can be studied and evaluated before building starts.

6.1 Funding sources show who the users are

The most significant sources of funding for the research projects that have been carried out in the VTI simulator have been The Swedish Road Administration, the research councils (KFB, VINNOVA etc.) and the EU. We have registered information for 39 projects;

- 23 have been totally or partially funded by public authorities (mostly The Swedish Road Administration and the former Trafiksäkerhets-verket)
- 13 have been funded by the research councils
- 19 by the EU
- 5 by industrial partners

The total is higher than 39, because many projects has several sources of funding. It is clear that industry's share is higher than is indicated by this estimate: many of the projects that are funded by industry are not in the public domain and we are therefore unable to provide precise information about them Volvo Car Corporation and GM/SAAB use VTI's simulator but also have access to their own simpler driving simulators. Since VTI's simulator is both advanced and expensive, self-funded projects are often carried out at facilities that are less expensive for the users. The more expensive VTI simulator is then used to verify results under the most realistic conditions possible. During the final phase of a project, VTI's simulator may also be used to decide between solutions that have resulted from tests in simpler simulators.

6.2 Co-operation with research institutions

Several of the projects with the VTI simulator have been carried out in co-operation with other research institutions, and it is clear that access to the simulator has in some cases been entirely decisive for the establishment of the research co-operation and also in cases where there was previous co-operation with VTI, the opportunity to carry out simulator studies has led to increased co-operation.

A good example is co-operation with medical research environments on the effect of drivers state of health on car driving, which was a central theme in many of the earliest projects with the simulator, Studies of sleep apnoea and effects of operative treatment were carried out in co-operation with the Ear Nose and Throat Department at the Karolinska Hospital and studies of sight defects were carried out in co-operation with the Ophthalmology Department at the same hospital. In a more recent study of the use of medication (Törnros, 1998) several hospital in Stockholm and Linköping were involved as co-operative partners.

The most recent studies of tiredness and driving are being carried out in collaboration with the Department of Psychosocial Medicine (IPM) at the Karolinska institute. Tiredness amongst drivers is a subject which is highly suitable for simulator studies, partly due to the ethical and legal considerations in allowing drivers who are short of sleep to drive in normal traffic. IPM’s research group is a word leader in tiredness and sleep, both with regard to the health related aspects and also for the implications for safety in transport and for work life in general. Simulator studies in collaboration with VTI’s specialists in traffic safety have therefore resulted in research at a high international level concerning the effects of tiredness in driver behaviour, and also for opportunities to detect signs of tiredness and use these in warning systems designed to prevent car drives from falling asleep at the wheel or driving when tired. (Ingre et al., 2006a; 2006b).

6.3 Co-operation with the authorities

Users from both business and industry highly value the opportunity to be able to use the simulator. With regard to collaboration with the authorities, it is primarily The Swedish Road Administration that has been the main cooperating partner. The regional road authorities see major potential for the use of the simulator to study safer road design. The fact that use is not more widespread is linked to the fact that simulator studies are too expensive for individual projects. Public basis funding for traffic safety related simulators is therefore desirable.

6.4 Co-operation with industry

The car industry has also been involved both as a financial contributor and as a co-operative partner in a number of projects. According to information from VTU a number of studies have been carried out with the car industry in addition to what appears in published works. This goes together with the fact that in many cases the car industry does not want the results to be made public. In cases where funding from sources other than the car industry are involved such as funding from PFF (Programrådet för fordonsforskning, under VINNOVA) or the EU, there is however some documentation. Studies for the car industry have largely dealt with different aspects of driving dynamics and steering, partly to investigate opportunities, limitations and validity of driving simulators, as a basis for the possible acquisition of their own simulators. Some studies look at how drivers experience different vehicle characteristics (e.g. Bertollini & Hogan, 1999; Nordmark et al., 1999).

In co-operation with Volvo Lastvagnar AB studies have been carried out on lorries (e.g. Aurell et al., 2000). According to information from VTI the simulator has been used for commissions from the car industry in the following countries (number of countries in brackets): Germany (1), USA (1), France (2), Japan (3), Sweden (4).

7 Practical application of research results

7.1 Examples from society and from industry

One important indicator of the benefit of traffic safety research is that the knowledge is out into practice, either in developing products that contribute to increased traffic safety, or in forming a basis for the authorities' decisions about measures that may be of significance for traffic safety.

Several of the projects have the explicit goal of evaluating different technical solutions for the design of vehicles and roads and since both The Swedish Road Administration and the car industry are involved in many projects, there is reason to believe that the results will be used, even though there are not yet many concrete examples of solutions that can be said to be the direct result of studies in the VTI simulator. Real traffic safety measures where knowledge from testing in the simulator can be important, are different information systems in cars, e.g. anti collision systems (Nilsson et al., 1992; Janssen & Nilsson, 1992), intelligent distance detectors (Nilsson, 1996; Nilsson & Nåbo, 1996), and systems for strengthening visual information, for example in fog (”visual enhancement system”, Nilsson & Alm, 1996). Knowledge about optimal design and any negative effects on driver behaviour are decisive for evaluating the implications for traffic safety. Since both intelligent speed restrictors and anti-collision devices have been installed in some Volvo models, there is reason to believe that testing using the simulator has contributed to this and to the design of the interface for these systems. (Here it should be assumed that there may also be vehicle technology solutions that are based on unpublished studies in the simulator, and hence that do not form part of this evaluation)

According to information from VTI a study commissioned by Volvo Technology AB in the lorry simulator directly contributed to solving a traffic safety problem linked to burst tyres on the front wheels of heavy vehicles (Petterson et al., 2006).

Another concrete measure is road marking and use of rumble strips and rumble fields to alert drivers who are inattentive or sleepy. How the marking should be designed to have the most positive effect on driver behaviour has been a central problem for a number of projects. (see Anund et al., 2005).

An example where knowledge from the simulator research has formed the basis for the authorities decisions applies to the question of legislation surrounding the use of mobile phones in cars. The Swedish Road Administration carried out a comprehensive assessment of this question (The Swedish Road Administration, 2003), where simulator studies formed an important element. While many other countries had implemented a ban on the use of hand-held mobile phones in cars and permitted the use of hands-free phones, The Swedish Road Administration concluded that there was no research justification for distinguishing between hands-free and hand-held phones with regard to risk. This was based in part on simulator studies that show that the main problem is linked to the cognitive load while talking and not to actually holding the telephone (Kircher et al., 2004). Hence there was no scientific justification for banning hand held phones unless hands free phones were also banned.

7.2 Some projects are not public

In many cases the car industry does not want to publicise the results of its research for reasons of competition. Thus also applies to a number of projects that are carried out in the simulator. VTI states that they are in continuous dialogue with the clients with a view to achieving greater openness. According to VTI, limited oneness is associated to 8-10 clients with a varying range of projects. There are also examples where the results from EU-funded projects, where the car industry is involved, have first been made public many years later. This means that the research at VTI's simulator is more extensive than would appear from the published works.

7.3 The significance of the VTI simulator for simulator research elsewhere

According to VTI, their simulator has been the system that other simulators are compared with, both with regard to technology for simulating acceleration forces and for achieving the minimum time delays in the picture graphics. The movement system has recently been used in simulators by Mazda and Daimler-Chrysler. The present simulator is used as a reference (”benchmark”) for car manufacturers who are planning advanced simulators.

Furthermore there is a strong connection between the simulator at VTI and planned simulators linked with the SAFER-collaboration in Göteborg. The aim is to coordinate and standardise simulation tools used by Chalmers, Volvo Car Corporation, Volvo AB, SAAB and VTI.

7.4 Could the knowledge have been obtained in other ways?

A key question in evaluating the benefit of the simulator research is obviously whether the same could have been achieved using other methods. Research in driving simulators mostly provides knowledge about how driver behaviour is affected in relation to the vehicle, traffic, the road system and the driver. Given that such knowledge can also be obtained using other methods it is important to ask whether the simulator research has provided knowledge that would have been difficult to acquire using alternative research methods.

There are three main approaches for direct studies of driver behaviour, each with its own strengths and weaknesses:

- Observations of cars in traffic
  - Advantages: driving in normal traffic
  - Disadvantages: limits with regard to the behaviour that can be observed, little control over the traffic situation and little knowledge from or about the drivers
- Studies in driving simulators
  - Advantages: Good control over research conditions and few limitations on observation of behaviour
  - Disadvantage: Limited realism
- Instrumented cars
  - Advantages: driving in normal traffic, few limitations on observation of behaviour and good knowledge of driver characteristics
  - Disadvantage: Limited control of the traffic situation when driving in normal traffic

To a large extent, these three approaches will complement each other. For example the simulator's advantage in varying research conditions can be used in order to choose conditions for follow up testing and validation in real traffic. On the other hand, data from driving in traffic using an instrumented car can contribute to generating hypotheses for systematic testing in simulators. With regard to the VTI simulator, our evaluation is that many of the important research results it has given would not have been achieved by relying on the other two approaches alone. Simulator research in general, alongside the other approaches has clearly contributed to increased knowledge about driver behaviour and safety, and the simulator at VTI has played an important role in achieving this.

8 Overall evaluation

There is little doubt that VTI's driving simulator has been of major significance for the scope and direction of traffic safety research at VTI, and hence also for Sweden. Through VTI's comprehensive international publishing and participation in EU projects, the simulator has become a trademark for VTI's traffic safety research, and has thus contributed to VTI acquiring an leading position amongst the traffic safety institutes in Europe.

With regard to scientific publications at VTI, international articles, based on projects in the driving simulator comprise at least a quarter of all the international articles about traffic safety that have been published by VTI in the last 20 years. Extensive citations of the published works also indicate that the simulator research at VTI has had significant influence on other traffic safety research. This influence could possibly have been even greater if international articles had been published on more studies from the simulator, for example the effects of road and traffic conditions on driver behaviour. On the other hand some of these studies have been directed at concrete, practical problems and may therefore have been important to the clients and to society, even though they have not been published internationally.

A greater degree of publicity for the results from studies on vehicle technology would also be an advantage, with regard to achieving the greatest possible spread of traffic safety knowledge. The driving simulator has enabled experimental studies of problems that it would be difficult to study using the other approaches. With regard to road design, signs and markings, one alternative is to carry out field studies where the measures are tested out on the roads. This is very resource intensive and the opportunities for testing different solutions are not as good as they are using the simulator. This also applies to some extent to equipment in cars. With the simulator there are opportunities to test several different solutions in order to select the most promising solutions for further testing in field trials. The simulator is therefore a significant supplement to other methods for developing and evaluating traffic safety measures.

Another problem area where it is difficult to carry out trials in normal traffic applies to various weaknesses amongst drivers, such as illness, use of medication, tiredness and the effects of alcohol and drugs, where legal and ethical considerations limit the opportunities. The simulator has therefore provided unique opportunities to study how best to highlight weaknesses that are significant for traffic safety.

When charting human conditions and limitations for safe driving, e.g. studies of mental and visual loading, the simulator has provided knowledge that is difficult to obtain in other ways, because it provides quite different opportunities for controlling the effects to which a driver is exposed than is possible in normal traffic. The opportunity to test drivers under conditions that seldom occur in normal traffic, but which can be critical when they first occur, is an important aspect of the simulator.

It is difficult, not to say impossible, to quantify the significance that the research in the driving simulator has had for traffic safety, e.g. by indicating the reduction in the numbers killed or injured. However, there is no doubt that the research has provided significant new knowledge, of particular relevance to traffic safety in Sweden, but also internationally. If it is assumed that there is a connection between the scope and quality of traffic safety research on the one hand and actual safety on the other, it can also be assumed that the driving simulator has contributed to increased safety.

9 Publications based on research in VTI's driving simulator

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VINNOVA´s publications

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VINNOVA Analysis

VA 2007:

01 Nanoteknikens innovationssystem

02 Användningsdriven utveckling av IT i arbetslivet - Effektvärdering av tjugo års forskning och utveckling kring arbetslivets användning av IT. *For brief version in Swedish and English see VA 2007:03 and VA 2007:13*

03 Sammanfattning - Användningsdriven utveckling av IT i arbetslivet - Effektvärdering av tjugo års forskning och utveckling kring arbetslivets användning av IT. *Brief version of VA 2007:02, for brief version in English see VA 2007:13*

04 National and regional cluster profiles - Companies in biotechnology, pharmaceuticals and medical technology in Sweden 2004. *Only available as PDF. For Swedish version see VA 2005:02*

05 Nationella och regionala klusterprofiler - Företag inom fordonsindustrin i Sverige 2006

06 Behovsmotiverade forskningsprogram i sektoriella innovationssystem. *For English version see VA 2007:15*

07 Effekter av den svenske trafikksikkerhetsforakningen 1971-2004. *For brief version in Swedish and English see VA 2007:08 and VA 2007:09*

08 Sammanfattning - Effekter av den svenska trafiksäkerhetsforskningen 1971-2004. *Brief version of VA 2007:07, for brief version in English see VA 2007:09*

09 Summary - Effects of Swedish traffic safety research 1971-2004. *Brief version of VA 2007:10, for brief version in Swedish see VA 2007:07.*

10 Effects of Swedish traffic safety research 1971-2004. *For brief version in Swedish and English see VA 2007:08 och VA 2007:09*

11 Svenskt deltagande i sjätte ramprogrammet. *Only available as PDF*

12 The role of Industrial Research Institutes in the National Innovation System

13 Summary - User-driven development of IT in working life - Evaluating the effect of research and development on the use of information technology in working life. *Brief version of VA 2007:02, for brief version in Swedish see VA 2007:03*

14 VINNOVAs fokus på effekter - En samlad ansats för effektlogikprövning, uppföljning, utvärdering och effektanalys

15 Needs-driven R&D programmes in sectorial innovation systems. *For Swedish version see VA 2007:06*

VA 2006:

01 End of an era? Governance of Swedish innovation policy. *For Swedish version see VA 2005:07*

02 Forskning och utveckling vid små och medelstora företag. *Only available as PDF*

03 Innovationsinriktad samverkan. *Only available as PDF*

04 Teknikbaserat nyföretagande i Sverige 1990 - 2003. *Only available as PDF*

05 Offentligt stöd till universitetens samverkansuppgift - en internationell kartläggning. *Only available as PDF*

06 Inkubatorer i Sverige - analys av indikatordimensioner och nyttoefektivitet. *Only available as PDF*

VA 2005:

01 Wood Manufacture - the innovation system that beats the system. *For Swedish version see VA 2004:02*

02 Nationella och regionala klusterprofiler - Företag inom bioteknik, läkemedel och medicinsk teknik i Sverige 2004. *For English version see VA 2007:04*

03 Innovation policies in South Korea and Taiwan. *Only available as PDF*

04 Effektanalys av nackskadeforskningen vid Chalmers - Sammanfattning. *Brief version of VA 2004:07, for brief version in English see VA 2005:05*

05 Impacts of neck injuries research at Chalmers University of Technology - Summary. *Brief version of VA 2004:07, for brief version in Swedish see VA 2005:04*

06 Forskningsverksamhet inom produktframtagning i Sverige - en ögonblicksbild år 2004

07 En lärande innovationspolitik - samordning och samverkan? *For English version see VA 2006:01*

08 Svensk trafiksäkerhetsforskning i tätposition - Framträdande forskare och forskningsmiljöer i statligt finansierad trafiksäkerhetsforskning 1949 - 2005

VINNOVA Forum

VFI 2007:

01 Universitetet i kunskapsekonomin *(Innovation policy in Focus)*

02 Tillväxtgenvägen - affärsinnovation i svenska tjänsteföretag *(Innovation policy in Focus)*

VINNOVA Information

VI 2007:

01 Forska&Väx - Program som främjar forskning, utveckling och innovation hos små och medelstora företag

02 MERA-programmet - Projektkatalog. *For English version see VI 2007:03*

03 The MERA-program - Projects. *For Swedish version see VI 2007:02*

04 DYNAMO 2 - Startkonferens & Projektbeskrivningar

05 IT för sjukvård i hemmet - Projektkatalog. *For English version see VI 2007:13*

06 VINNVÄXT - Ett program som sätter fart på Sverige! *For English version see VI 2007:09*

07 Årsredovisning 2006

08 Het forskning och innovationskraft - VINNOVA 2006. *For English version see VI 2007:10*

09 VINNVÄXT - A programme to get Sweden moving! *For Swedish version see VI 2007:06*

10 Red-hot research and innovation power - VINNOVA 2006. *For Swedish version see VI 2007:08*

11 Research and innovation for sustainable growth. *For Swedish version see VI 2006:20*

12 Projektkatalog - Genusperspektiv på innovationssystem och jämställdhet. Forsknings- & utvecklingsprojekt för hållbar tillväxt

13 *Under production.* IT in Home Health Care. *For Swedish version see VI 2007:05*

VI 2006:

01 VINNOVAs verksamhet inom Transporter. *For English version see VI 2006:07*

02 Årsredovisning 2005

03 Paving the Road. For Transport Innovation and Research

04 Drivkraft för tillväxt. VINNOVA

2005. *For English version see VI 2006:08*

07 VINNOVA´s activities within the Transport Sector. *For Swedish version see VI 2006:01*

08 A driving Force for Growth. VINNOVA 2005. *For Swedish version see VI 2006:04*

09 Komplexa sammansatta produkter - Projektkatalog 2006

10 VINNVINN - Mötesarena för nya affärsmöjligheter och arbetstillfällen

13 VINNOVA´s Activities in Biotechnology.

14 Arbetslivsutveckling - VINNOVAs satsningar inom arbetslivsområdet

16 Competence Centres in Figures - Kompetenscentrum i siffror

17 E-tjänster i offentlig verksamhet. *For English version see VI 2006:18*

18 E-Services in Public Administration. *For Swedish version see VI 2006:17*

19 Effektiv Produktframtagning - Projektkatalog 2006

20 Forskning och innovation för hållbar tillväxt. *For English version see VI 2007:11*

VINNOVA Policy

VP 2007:

01 Innovativa små och medelstora företag - Sveriges framtid. SMF-strategi från VINNOVA

02 Forskningsstrategi för miljöteknik - Redovisning av regeringsuppdrag till Formas och VINNOVA. *Only available as PDF*

VP 2006:

01 På spaning efter innovationssystem. *For English version see VP 2006:02*

02 In search of innovation systems. *For Swedish version see VP 2006:01*

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VR 2007:

01 Design of Functional Units for Products by a Total Cost Accounting Approach

02 Structural Funds as instrument to promote Innovation - Theories and practices. *Only available as PDF*

03 Avancerade kollektivtrafiksystem utomlands - mellanformer mellan buss och spårväg. Tillämpningsförutsättningar i Sverige. *Only available as PDF*

04 VINNVÄXTs avtryck i svenska regioner - Slutrapport. *For English version see VR 2007:06*

05 Utvärdering VINNVINN Initiativet

06 Effects of VINNVÄXT in Swedish regions - Final report. *For Swedish version see VR 2007:04*

07 Industry report on exhaust particle measurement - a work within the EMIR1 project. *Only available as PDF*

08 Swedish innovation journalism fellowships - en utvärdering. *Only available as PDF*

09 Rörlighet för ett dynamiskt arbetsliv - Lärdomar från Dynamoprogrammet

10 Miljöbilar och biodrivmedel - Hur påverkas Sverige av EUs direktiv?

11 Evaluation report by the VINNVÄXT International Review Team.

12 DYNAMO Arbetsgivarringar för ökad rörlighet - En slututvärdering av projekt om arbetsgivarringar inom DYNAMO-programmet

VR 2006:

01 Det förbisedda jämställdhetsdirektivet. Text- och genusanalys av tre utlysningstexter från VINNOVA

02 VINNOVAs FoU-verksamhet ur ett jämställdhetsperspektiv. Yrkesverksamma disputerade kvinnor och män i VINNOVAs verksamhetsområde

03 ASCI: Improving the Agricultural Supply Chain - Case Studies in Uppsala Region. *Only available as PDF*

04 Framtidens e-förvaltning. Scenarier 2016. *For English version see VR 2006:11*

05 Elderly Healthcare, Collaboration and ICT - enabling the Benefits of an enabling Technology. *Only available as PDF*

06 Framtida handel - utveckling inom e-handel med dagligvaror

07 Tillväxt stavas med tre T

08 Vad hände sen? - Långsiktiga effekter av jämställdhetssatsningar under 1980- och 90-talen

09 Optimal System of Subsidization for Local Public Transport. *Only available as PDF*

10 The Development of Growth oriented high Technology Firms in Sweden. *Only available as PDF*

11 The Future of eGovernment - Scenarios 2016. *For Swedish version see VR 2006:04*

12 Om rörlighet - DYNAMO-programmets seminarium 12 - 13 juni 2006

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VINNOVA´s mission is to promote sustainable growth
by funding needs-driven research
and developing effective innovation systems

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