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Driving and crash safety with antilock brakes (ABS)

by

Lennart Strandberg

Professor of Safety Technology, Chairman of the Board of VETA

1. Less accidents with ABS brakes if mileage is kept constant.

At the Stockholm car exhibition the view was offered that ABS brakes do not reduce the risk of accidents. A comparison had been made between insurance-related damage on an annual basis. However, if the same damage is correlated to mileage the results speak clearly in favour of ABS. With the sort of mileages we discuss in Sweden, the risk is almost 10% lower for cars with ABS.

A summary of an American report on anti-lock ABS brakes and accidents puts it like this: *"the comparisons presented in this report provide no evidence that the introduction of antilock brakes as standard equipment reduces collision or property damage liability losses resulting from real-world crashes"* see HLDI (1994) in the reference list.

The survey was presented at a car safety seminar on 940207 at the Stockholm car exhibition by Brian O'Neill, head of the IIHS and HLDI insurance institutes in the USA.

1.1. Annual risk versus mileage risk

I subsequently discovered in the IIHS monthly publication Status Report (IIHS 1994) that the damage had been related to insurance periods and not to mileage. This means that the results are probably unfairly weighted, since the two compared groups were of different ages and therefore covered different annual mileages.

The ABS cars were of model year 1992 whereas the cars with conventional brakes were from 1991. Damage was registered during the cars' first two years for ABS cars and the first three years for the control group. In addition, great care was taken to group the cars into three different categories. Great care was also shown in choosing cars which were not changed in any significant way other than that ABS became standard from the 1992 model.

When I discussed the mileage problem with him on the telephone, Brian O'Neill immediately sent me the complete report (HLDI, 1994). I now also had access to the confidence interval which was not available in IIHS (1994). This states the random variation area for the results. In the figures here they are marked with lines near the top of the risk bars. If the intervals overlap too much for one bar (without/with ABS) then the risk difference is not statistically significant. At the next measurement, chance may well alter the order of sequence. That was what happened with the results on the annual risk basis: none of the twelve pairs without/with ABS showed significant differences. See Table 2.

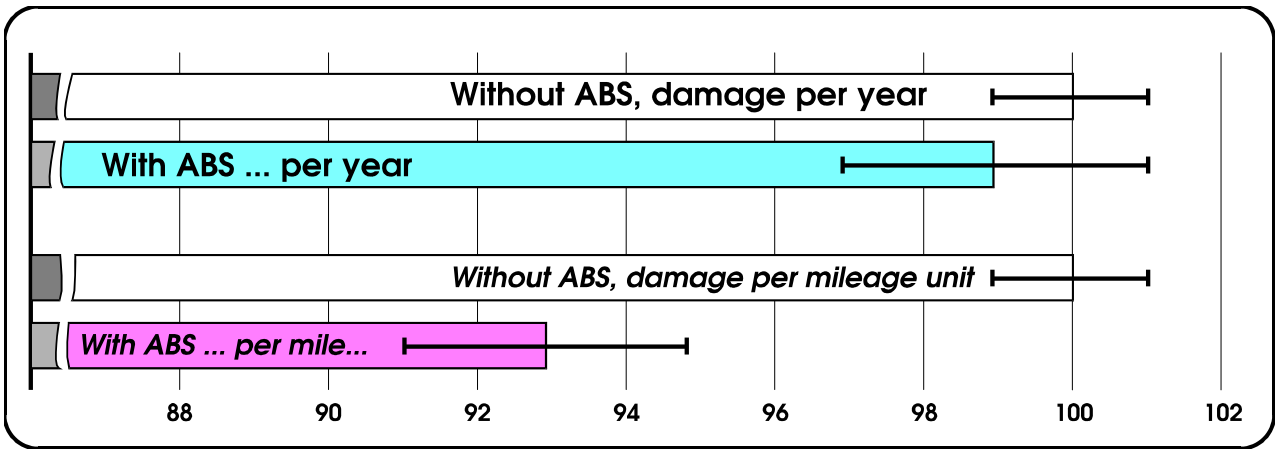

Figure 1 **Top:** Damage per insurance year without ABS (average value over three years with model year 1991) and with ABS (average value over two years with model year 1992). Data for Chevrolet Cavalier / Pontiac Sunbird throughout the USA, all the year round, according HLDI (1994).
Bottom: Accidents on a mileage basis. Annual risk with ABS as above reduced for higher mileages. The calculation example uses Swedish mileage data from Möller (1989)

1.2.Mileage risk clearly lower with ABS?

In order to obtain a rough idea of the extent to which the difference in the car's average age might affect the mileage risk, I produced corresponding annual mileages in Sweden from Möller (1989) and computed the annual risks to mileage risks. This made the risk index almost 10 % lower for ABS brakes on an average. The differences were always to the advantage of ABS and they were statistically significant in eleven of the twelve named pairs. See Table 2 and the example in Figure 1.

1.3.Lower insurance premiums with ABS?

Admittedly the mileage risks here are only calculated examples which perhaps would not argue equally in favour of ABS if these were converted into American instead of Swedish mileages. However, note that the mileage adjustment is only roughly 6% in the calculated example (see the tables). This still suggests completely different conclusions regarding the total safety effect of ABS brakes. An adjustment for the higher risk exposure of ABS cars might perhaps lead to the same resurgence for ABS in several cases in which risks were previously calculated on the basis of insurance statistics.

The insurance companies' premium-based income is more strongly biased towards time than mileage. The decision in some countries to withdraw the ABS discount from the insurance premium may therefore be unassailable from the purely financial point of view. On a national economy basis, however, this decision may be too hasty. It is sufficient that ABS cars are more expensive to repair or are driven somewhat higher mileages per year, in order for them to cost the insurance companies more even if their accident risk is lower on a mileage basis.

Table 1 Swedish passenger car mileages according to Möller (1989). Probably based on 1985 inspection data from ASB (1987).

Car age (years)	Annual mileage (km / year)	**Accumulated annual mileage (km / year)**
0 to 1	*26000*	
1 to 2	*22000*	24000
2 to 3	*19600*	22533
Average mileage quotient between two and three year old cars		**1.065**

Table 2 Accident risks with and without ABS brakes.

On the left: Annual risks from HLDI (1994, table 1) with 95 % confidence interval . HLDI's annual risk (Relative Claim Frequency) relates to the number of accident reports per year made on the basis of collision claims divided by the number of paid annual premiums. HLDI has made these results relative by setting the average value for all passenger cars at 100. Cars without ABS are of model year 1991 and this data refers to their first three years. Data from cars with ABS brakes, model year 1992, covers two years. *HLDI data is shown in italics.*

On the right: Here the mileage risk is calculated by dividing (only) the ABS cars' annual risk with their mileage relative to cars without ABS, using Swedish data from the above table. The mileage risk with ABS should therefore be compared with the annual risk without ABS (reference risk).

HLDI's selection to filter out the effect of ABS brakes on accident risks in the USA		Annual risk= 'Relative Claim Frequency' from HLDI (1994, Table1). Model year 1991 without ABS			Model year 1992 ABS as standard			HLDI annual risk divided by 1.065 for the higher mileage of ABS cars			Change in mileage risk with ABS calculated from Swedish mileages		
Parts of the USA Season	Car model	Lower Conf. Limit without ABS (ref.LCL)	Reference annual risk without ABS (ref.risk)	Upper Conf. Limit without ABS (ref.UCL)	Lower Conf. Limit with ABS (ann.LCL)	Annual risk with ABS (ann.risk)	Upper Conf. Limit with ABS (ann.UCL)	Lower Conf. Limit with ABS (mil.LCL)	Mileage adjusted risk with ABS (mil.risk)	Upper Conf. Limit with ABS (mil.UCL)	Risk change with ABS (mil.risk minus ref.risk)	Separation , conf.interv (ref.LCL minus mil.UCL)	Mileage risk with ABS signif. lower than ref.risk?
Whole, All	Chevrolet Cavalier, Pontiac Sunbird	*97*	*98*	*99*	*95*	*97*	*99*	89.2	91.1	93.0	**-7%**	**4.1**	**YES**
Whole, All	Chevrolet Corsica, Chevrolet Beretta	*110*	*112*	*114*	*108*	*111*	*114*	101.4	104.2	107.0	**-7%**	**3.0**	**YES**
Whole, All	Chevrolet Lumina, Oldsmobile Silhouette, Pontiac Trans Sport	*67*	*69*	*71*	*64*	*67*	*70*	60.1	62.9	65.7	**-9%**	**1.3**	**YES**
North, All	Chevrolet Cavalier, Pontiac Sunbird	*95*	*96*	*97*	*94*	*96*	*98*	88.3	90.1	92.0	**-6%**	**3.0**	**YES**
North, All	Chevrolet Corsica, Chevrolet Beretta	*109*	*111*	*113*	*108*	*112*	*116*	101.4	105.2	108.9	**-5%**	**0.1**	**YES**
North, All	Chevrolet Lumina, Oldsmobile Silhouette, Pontiac Trans Sport	*68*	*71*	*74*	*62*	*66*	*70*	58.2	62.0	65.7	**-13%**	**2.3**	**YES**
Whole, Winter	Chevrolet Cavalier, Pontiac Sunbird	*96*	*98*	*100*	*94*	*97*	*100*	88.3	91.1	93.9	**-7%**	**2.1**	**YES**
Whole, Winter	Chevrolet Corsica, Chevrolet Beretta	*110*	*112*	*114*	*105*	*110*	*115*	98.6	103.3	108.0	**-8%**	**2.0**	**YES**
Whole, Winter	Chevrolet Lumina, Oldsmobile Silhouette, Pontiac Trans Sport	*69*	*72*	*75*	*63*	*67*	*71*	59.2	62.9	66.7	**-13%**	**2.3**	**YES**
North, Winter	Chevrolet Cavalier, Pontiac Sunbird	*93*	*95*	*97*	*93*	*96*	*99*	87.3	90.1	93.0	**-5%**	**0.0**	**YES**
North, Winter	Chevrolet Corsica, Chevrolet Beretta	*107*	*110*	*113*	*108*	*114*	*120*	101.4	107.0	112.7	-3%	-5.7	NO
North, Winter	Chevrolet Lumina, Oldsmobile Silhouette, Pontiac Trans Sport	*68*	*73*	*78*	*61*	*66*	*71*	57.3	62.0	66.7	**-15%**	**1.3**	**YES**

1.4.Reading too much into "negative results"

Annual risks and their confidence intervals from the HLDI study (the left portion of Table 2) do not show any statistically reliable effects of ABS brakes. Medical tests suggest that the **results are negative**. However, it has not of course been proved that ABS brakes or other measures are without any effect, only that nobody has succeeded in proving any effect. This is a vital scientific principle which should apply in the area of traffic safety as it does within epidemiology, see Stöttrup Hansen et al. (1990).

Unfortunately we cannot say the same thing about the in-depth conclusions from the taxi survey in Munich from the 1980s. See Aschenbrenner et all 1992. This is quoted in many contexts as proof that ABS brakes do not improve traffic safety. A closer inspection, however, reveals that there are many confounders in the first analysis (1981-1983) based on 21 cars equipped with ABS brakes.

In the second evaluation period (1985/86) there were even fewer cars: 10 cars without and 10 cars with ABS brakes. Based on these circumstances it seems fairly natural that the risk indexes for all accident types did not differ with any degree of statistical significance.

Judging by the report's title, the taxi study aimed at showing how technical improvements are neutralised or even turned into increased risks through careless driver behaviour. Even though it is not the intention of the authors, this tendency is most likely the reason for discrediting ABS brakes in several portions of the report (Aschenbrenner et al. 1992).

As an example (page 53) the authors make it appear that it is the **cars**, not the drivers' behaviour, which raises the danger factor in cars with ABS. This impression is reinforced by selecting a confidence interval of only 68% in a comparison of accidents with and without ABS brakes. The difference would have appeared more random if the authors had kept to the generally accepted interval of 95%.

Similar interpretations have also been offered by the HLDI survey in many contexts after the presentation at the car exhibition on 940207.

2. Analysis of driver and vehicle risks require methods other than studies of road risks

Safe cars and skilful drivers drive more often in slippery conditions, in the dark and in tough traffic environments. They may therefore have a higher risk index than their more hesitant counterparts. This is especially true if one only relates the number of accidents to the total mileage, irrespective of where and when that mileage is covered. Traditional measurements and methods of determining risks in traffic environments may in such a case be directly misleading.

2.1.Misleading exposure index

The accident risk for a particular stretch of road is often calculated by the number of accidents divided by the accumulated mileage, expressed as a number of vehicle kilometres (known as exposure). If we in the same way compare how the accident risk is affected by a specific difference between drivers or vehicles, it is quite easy to disguise the true connection – or even suggest an inaccurate connection – through confounders which have not been taken into consideration in the analysis.

In the above HLDI study the differences in age and annual mileage could be regarded as such a confounder. However, one could also ask why the number of insurance years was chosen as the exposure index instead of the actual mileage covered.

Even if one compares vehicles of the same age when evaluating the effect of ABS brakes on the number of accidents, one can nonetheless suspect that cars with ABS are driven for higher mileages every year than cars with simpler equipment. This too can distort the results of the survey carried out by Sweden's Folksam insurance company, which the mass-media presented in week 20, 1994. See for example Tjernberg (1994) or Öinert (1994).

However, not even the correct mileage is sufficient if it is not differentiated as per traffic environments with varying risk indexes. Assume that cars with ABS brakes are driven for higher mileages on safer roads, for example motorways. This would result in underestimation of the accident risk with ABS brakes. The opposite is also possible, for example if driving was less likely to be curtailed by slippery road conditions or darkness if the car has ABS brakes.

2.2.Experience-based risk analysis

Epidemiological methodology could be used here. Together with the police in Sweden's Östgöta County, we conducted a case-control study on a trial basis during a few winter months. See Strandberg (1991a). Immediately after every road accident, the police registered the same data both for the vehicle involved in the accident (the case) and for five vehicles which passed the accident site (control).

This allowed us to determine the extent to which the accident risk was affected by factors such as driver age, vehicle type (truck, bus or passenger car), studded tyres, etc. without needing to compensate for the fact that middle-aged drivers, heavy-duty vehicles or studded tyres may be over-represented in the traffic environment in slippery road conditions. The effect of confounders in road and traffic environments is neutralised in this way since they are similar for both the case group and the control group.

This method is well suited for surveys into how accident risks are affected by ABS brakes. However, just as with epidemiology, planning of this survey requires considerable practical experience. Otherwise it is possible to overlook several of the most relevant risk factors. Spurious correlations and distorted results may also occur if one disregards the vital interaction between various driver and vehicle variables which are well-known among traffic professionals.

Project planning therefore begins within VETA as soon as possible using experienced police officers, driving instructors, vehicle technicians, professional drivers etc. Please register your interest and suggest further variables apart from ABS.

3. Increase know-how about the complexity of the accident sequence!

ABS brakes, driving training and other specific safety measures sometimes seem to trick the driver into driving in such a way that the total accident risk increases. Some traffic experts have taken this as justification for replacing such measures with control measures and general attitude control. What we need instead is **additional effort** based on the multi-faceted background to actual accident sequences.

3.1.Impractical theory on risk compensation

It has recently become fashionable among some traffic experts to devalue the safety effects of such things as ABS brakes, driver training and road improvement. Without scientific justification they refer to the so-called theory of risk compensating behaviour, compare with Wilde (1982), OECD (1990). Negative results are considered to confirm the theory, see page 3.

They also base their assessment on an assumption that car drivers can, but do not want to drive more safely, even though accidents always come as a surprise and are always unintentional. They therefore suggest closer monitoring and general attitude control instead of specific technical and pedagogical measures.

Here instead we suggest a strategy whereby practical safety measures are always supplemented such that road users realise how small a portion of the risk panorama is helped by the relevant measure. After zooming in on a risk and rectifying it one should zoom out again to remind road users of all the risks which still remain. See Strandberg (1993a).

Honing one's driving skill for specific types of situation and technical advance should thus be followed up by demonstrations in which the driver is made fully aware of the variables which have not been rectified but which affect others in actual road accidents.

As regards ABS brakes, the car industry can also improve the technology so that all the undesirable side-effects and disadvantages are reduced as and when they are discovered, in interaction with experienced drivers, driving instructors, inspectors and police etc.

We at VETA are concentrating our efforts in this direction. See Strandberg (1995a&b).

3.2.Do we drive more carelessly with ABS?

In this context it is fairly pointless to evaluate the effect of ABS only on the basis of specific accident types, where braking properties are of particular importance, for example rear-end shunts. See Öinert (1994). The fact that ABS brakes offer positive safety effects has been confirmed previously, for example in the taxi survey from Munich by Biehl et al. (1987), see also Aschenbrenner et al. (1992).

Those who devalue the effect of ABS brakes do so because the driver is assumed to drive more carelessly and faster in general when he or she has ABS. This would give an overall effect on the number of accidents which is not in favour of ABS.

As regards driver behaviour Aschenbrenner et al. (1992) used double blind tests to establish that their taxi drivers drove more aggressively when their cars were equipped with ABS even in situations in which ABS brakes did not have any effect on the safety margin.

According to conversations and correspondence which I have had with one of the authors (Bernhard Biehl), the observers did not know if the cars had ABS brakes or not. Furthermore, the taxi drivers believed that the observers were normal customers. That is why this method is known as the double blind test.

There is no real doubt that the taxi drivers studied in Munich at the start of the 80s drove with lower safety margins than they were aware of, when their cars were equipped with ABS. Since ABS brakes are now far more common they should not affect driver behaviour as clearly and in the same way. However, people who work with driver training confirm that the safety potential of ABS brakes is still not exploited to the full.

3.3.Pulsating brake pedal requires familiarity

One problem pointed out by many people is the pulsating sensation in ABS brake pedals. This is sometimes misinterpreted as indicating that something is wrong. Inexperienced drivers therefore released the pedal just when braking power was most needed.

This driver reaction was new to me when we in my research team began testing ABS brakes with normal drivers on thick ice, in winter 1990. Volvo had supplied us with four cars in which the ABS function could be engaged and disengaged at the flick of a switch on the instrument panel.

However, our associates from the Women's Auxiliary Corps (SKBR), who issued their driving instructions from the passenger seat soon saw that many drivers were surprised and released the pedal when they felt the typical ABS pulsation for the first time.

We therefore gave the drivers a few test runs with ABS before the measurements were undertaken. This simple measure was sufficient for the results with ABS to be far better than the results obtained without ABS brakes. See below or Strandberg (1991b). Volvo immediately passed on our observations to their dealers.

3.4.Training counteracts misunderstanding

Similar misunderstanding regarding ABS was seen clearly in an experimental study with 100 drivers from Renault in France in summer 1991. They were split up into four equally large groups with different prior know-how about ABS. The drivers drove the same type of car with or without ABS along a route with many crossroads and junctions. As they were driving they suddenly came upon a dummy car immediately in front of them, forcing them to both to steer and brake in order to avoid a collision. See Priez et al. (1991).

In the Renault survey the emergency avoidance manoeuvre failed for all the 25 drivers who did not have ABS brakes. Although they had locked their front wheels in their braking attempt, many (40%) still tried to steer. The same behaviour was recorded for 50% of those drivers who had ABS but did not know about it. Owing to the fact that the ABS brakes functioned as intended they were far more successful in their emergency avoidance manoeuvre. The third driver's group knew that their cars had ABS. Many of them

therefore believed that they did not need to steer (almost 60% refrained from steering). They were recorded as having more collisions than the group which did not know that their cars were equipped with ABS brakes. The best results were obtained by those 25 drivers in ABS cars who had received half a day's training on ABS brakes about two months before the experiment was carried out. 80% of these drivers steered away.

The benefits of ABS brakes were at least as clear in the early 70s in experiments on ice tracks on behalf of the Swedish development process for safety cars (ESV). The 55 drivers taking part in this study were also subjected to surprise dummy cars in crossroads and junctions, in which they were driving cars with ABS activated without knowing about it. More than 80 % of the drivers steered and braked simultaneously. See Johnsson & Knutsson (1973).

Of course it is important to highlight the limitations, side-effects and disadvantages of ABS. One such dilemma is that increased steering ability often leads to poorer stability, refer to the term *kursstabilitet* (directional stability) in the Swedish National Encyclopaedia (Strandberg 1993b). However, it is as important that the benefits are established so that they can be utilised in traffic safety work and are not unfairly disregarded in the shadow of other less effective measures.

3.5. ABS brakes in motorcycles & heavy vehicles

In the seminars after VETA's ordinary general meeting on 940520 the problem of motorcycle drivers applying their handbrakes swiftly but with just enough pressure in emergency situations was discussed. Training expert Ioannis Minoudis had noticed this even with more experienced motorcycle riders in emergency situations.

Station manager P-O Franssén from the Swedish motor Vehicle Inspection Company observed that motorcycles should therefore be equipped with pedal-operated ABS brakes which distribute brake power optimally between the front and rear wheels. The driver would then only need to press the brake pedal without having to release his grip on the handlebars.

Another example is the considerable safety potential of ABS brakes on heavy-duty vehicles. With their far greater number of wheels and varying load distribution, such rigs with ABS brakes can slash braking distances to just a third compared to conventional brakes in slippery road conditions (Strandberg, 1987, table 4). At high speed, this means that an ABS-equipped rig can come to an emergency standstill while a rig with conventional brakes will go on to crash with more than 80% of its initial speed, e.g. at almost 60 km/h if braking started at 70 km/h. See Figure 2.

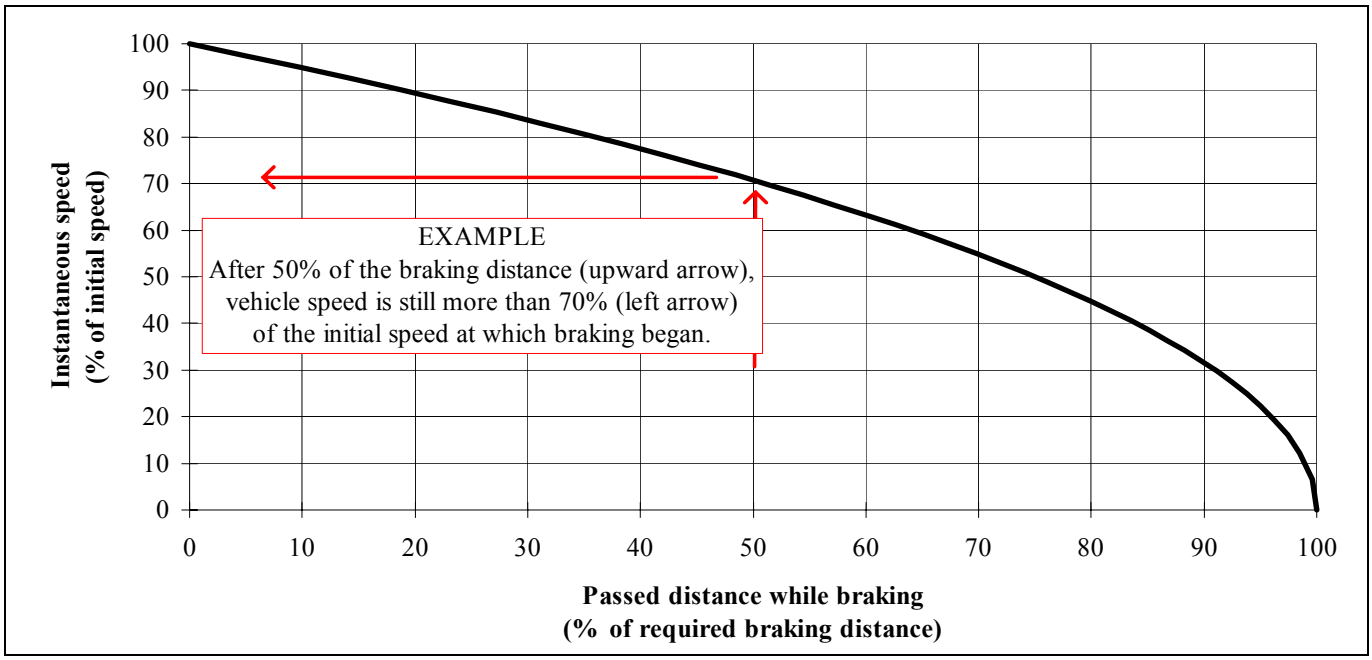

Figure 2 Speed at different points under constant deceleration.
The diagram shows that small differences in braking distance have a major effect on crash speed.

3.6.ABS for better crash safety

Similar differences in crash speeds may perhaps save many of the roughly 100 people who die every year when their cars crash into trucks or buses. Table 15 in the Central Bureau of Statistics Traffic Accident Survey records 91 fatalities (12% of all 745 killed) in 1991, 105 (14% of 759) in 1992, 77 (12% of 632) in 1993 and 73 (12% of 589) in 1994.

Even if the deceleration and braking distance improvements offered by ABS are less for cars, they can nonetheless result in considerable reductions in crash speeds and impact force.

Our winter study on frozen Lake Hemsjön in Sweden used 52 drivers in Volvo 440s and 740s. Average deceleration was just over 10% higher with ABS activated (the 95% confidence interval stretched from 9% to 15% improvement, see Strandberg, 1991b, page 14). According to Figure 2, this means that when the average car with ABS brakes had come to a complete standstill, the same driver in the same car but with the ABS function disengaged continued ploughing on ahead at just over 30% of his initial speed.

ABS can thus improve both driving and crash safety. This fact is often overlooked in the advice given to car buyers to invest in airbags **instead of** ABS brakes, see the article by Danielsson (1994). The superiority of ABS brakes lies to a considerable extent in the fact that they can in addition improve safety for unprotected pedestrians as well as for drivers who are themselves unable to pay for such safety technology.

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Author's address (2005): Lennart Strandberg, Box 1, SE-590 54 Sturefors, Sweden. Phone: +46 70 54321 00.
E-mail direct Lennart@stop.se or via http://www.stop.se/

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