

A SURVEY OF CANADIAN DRIVERS' KNOWLEDGE ABOUT AND EXPERIENCE WITH ANTI-LOCK BRAKES

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ABSTRACT

This study presents the results of an analysis of two sources of data: a sample containing 1392 drivers of ABS-equipped vehicles, and a dataset containing 405 ABS-related complaints. Survey respondents were asked about the purpose of ABS, the correct use of ABS, and whether their ABS had either prevented a collision or caused them to have one in the past two years. The complaints data were examined to determine to what extent the reported problems arose as a result of driver mis-use and/or mis-understanding of ABS.

About 18 percent of the ABS-users surveyed thought that pumping the brakes was the correct way to operate them, while close to 40 percent thought that the purpose of ABS was to stop faster, and/or prevent all skids. About 47 of the ABS-related complaints involved loss of control/extended stopping distance incidents with normally-operating ABS; about 73 percent of these incidents had resulted in collisions.

INTRODUCTION

The potential of ABS to reduce collisions by improving driver control has been well-documented in controlled testing environments. However, the results of the collision-based research on the effectiveness of anti-lock brakes made possible by the widespread fitment of ABS in the early 1990s have demonstrated both positive and negative effects of ABS.

On the positive side, antilock brakes have been associated with significant reductions in multiple vehicle collisions, on both good and bad road surfaces. On good road surfaces, ABS has been associated with a nine percent reduction in multivehicle frontals (Hertz et al., 1995); a six percent reduction in side impacts (Evans and Gerrish, 1996); and reductions of 22 percent in crashes fatal to non-ABS road users, and 20 percent in multiple-vehicle crashes fatal to occupants of the other motor vehicle (Farmer et al., 1996).

Decreases have also been observed for bad road surfaces, i.e., wet/snowy/icy pavement; these reductions have been estimated variously at 13 percent (Evans, 1995), 28 percent (Kahane, 1994), and 35 percent (Hertz et al., 1995). Reductions for fatal multivehicle collisions

only have been estimated at 24 percent (Kahane, 1994), and 35 percent (Hertz et al., 1995), and for fatal pedestrian involvements at 27 percent (Kahane, 1994) and 34 percent (Evans, 1995).

The research has consistently shown that the clearest effect of ABS is for striking front-to-rear collisions on wet/snowy/icy surfaces; Kullgren (1994) has observed that the ABS vehicle is seldom the striking vehicle in a rear-end collision, and both studies which calculated the effect in terms of percent reductions estimated them at 32 percent (Evans, 1995), and 39 percent (Kahane, 1994).

Conversely, while ABS reduces the risk of crashing into a lead vehicle, it appears to increase the risk of being struck in the rear (Kullgren, 1994; Kahane, 1994; Evans and Gerrish, 1996); for example, Kahane (1994), observed a 27 percent increase in "struck in the rear" collisions for ABS-fitted vehicles, while Evans and Gerrish (1996) calculated an increased risk of being struck in the rear of about $(30 \pm 14)\%$ for these cars.

The research has also consistently shown ABS to be associated with statistically significant increases in single vehicle collisions of various types on dry and wet surfaces (Kullgren, 1994; Kahane, 1994; Evans, 1995; Hertz et al., 1995; Farmer et al., 1996). Kahane observed a 29 percent increase in fatal single vehicle collisions on dry roads, and increases in every type of non-fatal single-vehicle collision studied, ranging from 15 percent for frontal impacts with fixed objects to 49 percent for rollovers, and 19 percent for all single-vehicle collisions combined; the increases in non-fatal single vehicle collisions were significant on both dry pavement (up 17 percent) and wet pavement (up 24 percent). Evans (1995) noted a 44% increase in rollover risk, while the second NHTSA evaluation (Hertz et al.) found that ABS was associated with increases in non-fatal single collisions on good and bad road surfaces combined, including a 24 percent increase in rollovers, a 15 percent increase in run-off-road collisions with parked vehicles or fixed objects, and a 36 percent increase in side impacts. Hertz et al. also found that ABS was associated with increases of 60 percent for fatal rollovers, and 91 percent for fatal side impacts with fixed objects. Most recently, for ABS-fitted GM mid-size cars, Farmer et al. noted a 17 percent overrepresentation in all fatal single-

vehicle collisions and disproportionate representations of ABS vehicles in collisions fatal to ABS vehicle occupants of 39 percent (all single-vehicle crashes), 47 percent (single-vehicle running off road); 37 percent (rollover crashes); and 29 percent (single-vehicle rollovers).

Given this mix of positive and negative effects, it is not surprising that attempts to demonstrate an overall benefit of ABS have resulted in failure to detect a net benefit (Highway Loss Data Institute, 1994) or the detection of only a very small net benefit of 3 percent (Evans, 1995).

It is fairly easy to explain the benefits associated with ABS in terms of the stopping tests, i.e., significant reductions in multivehicle collisions were found for collisions involving hard braking on slippery surfaces. However, explanations for the negative effects are both more difficult to explain and necessarily speculative in the absence of causal data.

The most easily understood negative effect of ABS is the increased likelihood of being rear-ended in an ABS-fitted vehicle. The most likely explanation of this finding is that the superior braking ability of a lead vehicle will logically put it at a higher risk of being hit by a following vehicle not fitted with ABS. However, it seems reasonable to suggest that this negative effect will disappear as more and more vehicles are equipped with antilock brakes.

The increase in single-vehicle collisions for ABS-equipped vehicles, however, is neither consistent with the stopping tests, nor as easily interpreted. One possibility is that it is a negative consequence of the very advantage that ABS provides, i.e., the ability to steer in an emergency situation. It is entirely possible that a certain proportion of rear-enders are simply being converted to single-vehicle collisions: the driver of an ABS car in an emergency situation may steer off the road rather than rear-end the lead vehicle, but in doing so, increases the risk of rollover or collision with a fixed object. The use of steering/avoidance maneuvers may also explain the increase in oncoming collisions detected by Kullgren (1994), if driving off the roadway is not an option and the driver attempts an avoidance maneuver that takes the vehicle even briefly into the opposing lane. Furthermore, given that ABS cannot be expected to reduce stopping distance appreciably on dry pavement (Kahane, 1994), the negative effect may be particularly evident on this type of road surface.

The most difficult negative effect to explain, however, is the significant increase in single vehicle collisions on wet/slippery pavement, given that ABS is designed to shorten stopping distance on these surfaces. This finding perhaps offers the strongest evidence for an explanation in terms of driver behaviour. Research on

behavioral adaptation has suggested that drivers may react to ABS technology by maintaining higher speeds, performing more dangerous maneuvers, accelerating more quickly, etc. (Grant and Smiley, 1993). Others have suggested that drivers of ABS cars may be using the brakes incorrectly, by either relieving pressure on the brake pedal or pumping the brakes (Williams and Wells, 1994). This study focuses on drivers' knowledge about, and understanding of, ABS in an attempt to provide some insight into the negative benefits associated with ABS.

METHOD

Two sources of data were used: a public perception survey, and a database consisting of ABS complaints, and investigations.

The public perception data were generated in 1997 when Transport Canada contracted COMPAS Inc. to undertake a telephone survey on the driving public's perception of road safety in Canada. The research objectives were to position drivers' road safety concerns in the context of other modes of transportation, identify road safety issues of importance to them, evaluate their knowledge of road safety issues and discern their priorities for safety intervention.

Following a series of focus-group and telephone pre-tests, the survey was administered nationally between November 28 and December 15, 1997. The sample frame provided for a minimum of one hundred interviews per province and fifty per territory. To ensure sufficient representation in each region, smaller jurisdictions were oversampled, and the final data weighted to ensure that the results were representative of the national driving population. To ensure randomization within a household, the "next birthday" method of respondent selection was employed. The final sample consisted of 2,286 respondents, all of whom were at least 16 years of age and had driven a motor vehicle within the past twelve months.

The survey consisted of one hundred and two questions, a small subset of which were specifically related to anti-lock brakes. All respondents, whether they reported driving an ABS vehicle or not, were asked what the purpose of ABS is, i.e., stop faster, steer while braking, prevent all skids or other. Multiple responses were allowed, thereby enabling a clear picture of the sample in terms of their understanding of ABS, i.e., complete (those who gave only one response, and it was the correct one), partial (those who gave at least one incorrect response along with the correct one); and no understanding (those who gave only an incorrect response or responses).

The respondents who reported having driven a vehicle fitted with ABS were asked the remaining questions:

- how they would use ABS on wet or icy pavement (apply steady pressure; pump the pedal; other);
- whether their anti-locks had helped them avoid a collision in the last twenty-four months; and
- whether their anti-locks had caused a collision or near-collision in the last twenty-four months.

Those who thought that their ABS had helped them avoid a collision were asked two further questions: what they had almost collided with (another vehicle, fixed object, pedestrian, etc.); and how they had avoided the collision (e.g., braked and steered around the obstacle, braked and drove off roadway, etc.).

Those who thought that their anti-lock brakes had caused or nearly caused them to have a collision were asked two follow-up questions: the type of incident (collision/near-collision with another vehicle, fixed object, pedestrian, etc.); and whether the incident had occurred on-road or off-road.

The second data base consists of all ABS-related complaints made to Road Safety's defects investigation division since the mid-1970s (N=405). Information on the vehicle type, make and model year; collision or near-collision details; complainants' perceptions of the brake-related problem and the investigators' assessments were extracted, coded and entered into an electronic data base. Although these data cannot be assumed to be representative of all ABS drivers, or even all dissatisfied ABS drivers, these data can provide interesting and valuable information on experience with, and understanding of, anti-lock braking systems among a particular subset of drivers who use ABS.

The main thrust of the present analysis, then, is to describe ABS drivers' knowledge, understanding and use of, ABS, and to some extent, their positive and negative experiences with ABS. Given that the data available to the present study are nominally or ordinally scaled, differences were tested using the chi-squared test of significance.

RESULTS

Sixty-one percent of the 2286 survey participants reported having driven an ABS-fitted vehicle (N=1392), and consisted of 832 men (59.8 percent) and 560 women (40.2 percent).

Knowledge About ABS - Respondents were asked whether the purpose of ABS was to enable the driver to steer while braking hard, to stop faster, to prevent all skids, or had some other purpose; multiple

responses were allowed. Although ABS will decrease stopping distance on wet pavement, it will increase it on others, e.g., snow, slush or gravel. Likewise, although ABS will prevent braking-related skids, it will not prevent skidding caused by traveling too quickly on slippery, i.e., icy or snowy, pavement. Since the main purpose of ABS is to enable steering while braking hard, this was defined as the "correct" response.

Interestingly, less than half (44.1 percent) of the drivers stated that the only purpose of anti-lock brakes was to enable them to steer while braking hard. A further 16.1 percent gave at least one incorrect response (stop faster and/or prevent all skids) with the correct one, while a notable 39.8 percent omitted "steer while braking" entirely and gave only one or more incorrect responses.

Operation of ABS - The second measure of drivers' understanding of ABS was the question about the correct method of applying ABS while traveling on an icy/slippery surface. Although 78.2 percent of them gave the correct response (apply steady pressure), 18.1 percent reported incorrect usage, i.e., pumping the brakes, while a further 3.7 percent didn't know.

Not surprisingly, there was a strong association between these two measures of ABS understanding. Those with full or partial knowledge about the purpose of anti-lock brakes, i.e., included "steer while braking" among their answers to the previous question, were much more likely to respond that the correct method of using ABS is to apply steady pressure ($\chi^2 = 33.08$, d.f. = 2, $p < .00000$). Although neither variable was related to age, an effect of gender was detected for both. Men ($n=832$) were more likely to report correctly both the purpose of ABS ($\chi^2 = 29.58$, d.f.=2, $p < .00000$) and the method of use ($\chi^2 = 26.21$, d.f.=1, $p < .00000$) than were women ($n=560$).

Collision Frequency - The public perception survey contained a question on the frequency of collisions that was asked of all survey respondents, i.e., it was not part of the subset of questions specifically for ABS drivers, and asked only how many collisions the respondent had had in the past two years. In the absence of data on the collision type (single-vehicle versus multiple-vehicle) or severity, it has limited analytical value. Nevertheless, it does provide a basic measure of collision involvement for the ABS drivers, as a complement to the later questions on collisions the drivers considered to be related to ABS in some way.

The number of (non-ABS-related) collisions in the past two years was not found to be related to either kilometers traveled in the last year ($\chi^2 = 3.678$, n.s.) or sex ($\chi^2 = .003$, n.s.). However, a strong association between collision involvement and age was detected, and it was in the expected direction, with younger drivers

(16-39 years of age) much more likely to report a collision than drivers 40 years of age or older ($\chi^2 = 19.04230$, $p < .00001$). Furthermore, the age association held for both males ($n=829$, $\chi^2 = 14.855$, $p < .0001$) and females ($n=556$, $\chi^2 = 4.767$, $p < .05$). Number of collisions was not found to be associated with either knowledge about the purpose of ABS ($\chi^2 = .315$, n.s.), or correct usage of ABS ($\chi^2 = .026$, n.s.) for all ABS drivers combined. However, given the relationship demonstrated previously between sex and both ABS knowledge and usage, separate analyses were run for women and men.

It was found that female drivers younger than 40 years of age with no knowledge of the purpose of ABS were more likely to report at least one collision than were women with at least partial understanding of ABS ($N=275$, $\chi^2 = 4.845$, $d.f.=1$, $p < .05$). No relationship between ABS knowledge and number of collisions was found for men ($N=831$, $\chi^2 = 2.386$, n.s.), or between ABS use (steady pressure versus pumping) and number of collisions for either sex.

ABS-related collisions - All ABS drivers were asked whether they believed that their anti-lock brakes had helped them avoid a collision in the previous two years, and conversely whether they thought the brakes had caused them to have a collision in the same time period.

A total of 370 respondents (26.6 percent) reported that their ABS had enabled them to avoid a collision. Of these, 73.8 percent reported that they had avoided colliding with another vehicle, 12.4 percent had avoided a collision with a fixed object, 2.9 percent had avoided a collision with either a pedestrian (2.4 percent) or a cyclist (.5 percent) and 3.8 percent had avoided hitting an animal.

Conversely, 6.6 percent ($n=92$) of the 1392 ABS users reported that their anti-locks had caused them to have at least one collision or near-collision in the past two years. About 37 percent of the incidents involved another motor vehicle (29 collisions, and 5 near-collisions), with 17 percent of drivers ($n=16$) reporting either a fixed object/off road collision ($n=14$) or near-collision ($n=2$). An additional 34 percent reported incidents in which they experienced extended stopping distance, i.e., went through an intersection, red light or stop sign. Overall, 95.7 percent of these drivers reported the incident to have occurred on the roadway, with only 4.3 percent reporting that the incident occurred off-road.

Interestingly, knowledge about the purpose of ABS was not associated with the purported contribution of ABS to either collision avoidance ($\chi^2 = .632$, n.s.) or causation ($\chi^2 = 1.197$, n.s.). Similarly, no association was found between ABS usage (steady pressure versus pumping) and either collisions purportedly avoided due

to ABS ($\chi^2 = 2.07$, n.s.), or caused by ABS ($\chi^2 = 1.142$, n.s.).

Among those who reported that ABS had helped them avoid a collision, 37.3 percent stated that they did so by braking and steering around the obstacle, while 5.7 percent reported braking and steering off the roadway without further incident. However, 47.6 percent ($n=176$) reported that they avoided the collision by braking and stopping in time; in the absence of data on the pavement conditions, it is not possible to determine whether their ABS provided them with better stopping capability than conventional brakes would have.

The complaints data are remarkably similar in distribution of incident type and location to those surveyed who reported an ABS-related incident. As such, they should provide some insight into the ABS-related incidents reported by the 92 survey respondents.

First, and notably, is the fact that about 50 percent of the incidents that were attributed to ABS by the complainants turned out to be ABS malfunction or failure; about 30 percent of these involved Transport Canada recalls or major investigations, 12 percent were isolated ABS failures, and the remainder involved miscellaneous problems such as wheel speed sensor malfunctions and leaking ABS controllers. A further three percent of incidents were attributable to other vehicle problems (1.2 percent) or undeterminable (2.5 percent).

However, in 47 percent of the incidents reported to the investigations division, the drivers were reporting ABS failure or malfunction when the brakes were functioning normally. Overwhelmingly, these were loss of control incidents: the driver had experienced extended stopping distance, i.e., unwillingly run a red light or stop sign. Moreover, a considerable 81.6 percent of these cases occurred in weather/road conditions that were less than ideal, e.g., snow and/or slush.

Interestingly, the distribution of incident type among the ABS complaints is nearly identical to the survey respondents who reported a collision or near-collision due to ABS. Of the 405 complaints received, 40.2 percent involved a specific incident, e.g., a collision or near-collision, versus only 6.6 percent of the ABS drivers surveyed. However, of these, about 39 percent involved a collision or near-collision with another motor vehicle (versus 37 percent of those surveyed who reported incidents), 21 percent involved hitting or nearly hitting a fixed object or the ditch (versus 17 percent), and 36 percent (versus 34 percent) reported a loss of control incident, such as skidding or sliding through an intersection. About 95 percent of the complainants (compared with 96 percent of the survey respondents who reported an ABS-related incident) reported that the incident occurred on the roadway, rather than off the

road. Although caution should be exercised when generalizing from the complaints data to the survey data, it seems reasonable to surmise that a comparable percentage of the incidents attributed to ABS by these drivers were actually due to lack of knowledge about the longer stopping distance required by ABS on certain road surfaces, given the similarity of the distributions of incident type in both data sets.

CONCLUSION

The association of ABS with increases in various collision types, especially single-vehicle run-off road crashes, found everywhere in the evaluation literature has raised questions regarding drivers' knowledge about, (mis)use and (mis)understanding of anti-lock brakes. The present paper represents a preliminary step in the exploration of the human factor that may be underlying the negative benefits associated with ABS.

The survey data are, first of all consistent with the research that demonstrates the potential of ABS to reduce collisions. About 27 percent of the survey respondents reported that ABS had enabled them to avoid a collision, whereas only seven percent reported that ABS had caused them to have a collision or near-collision. Furthermore, a considerable 74 percent of those who identified a positive benefit reported that it was a collision with another motor vehicle that had been averted. Nevertheless, only 37 percent of them reported that they had avoided the collision by braking and steering around the obstacle, i.e., used ABS in the way it is intended to be used, while six percent reported that they had braked and steered off the roadway to avoid the crash. While those respondents had reported doing so without further incident, it is noteworthy that 17 percent of the respondents who reported a negative benefit of ABS had experienced a collision or near-collision by steering off the roadway, with another 34 percent reporting a loss of control incident, i.e., running a red light or stop sign.

The study also demonstrated a level of misunderstanding about anti-lock brakes that is consistent with findings reported elsewhere (Williams and Wells, 1994): close to 40 percent of the survey respondents failed to identify the ability to steer while braking as a purpose, main or otherwise, of anti-lock brakes, while about 20 percent thought that pumping the brakes was the correct method of using ABS. Additionally, women were less likely than men to state the correct purpose of ABS or to state the correct method of use. The need for public education, and its potential to reduce collisions, is further supported by the observation that women under 40 years of age with the least

understanding of ABS (i.e., who omitted "steer while braking" from the list of purposes of ABS) were more likely to report at least one collision than were women who demonstrated at least partial understanding of ABS.

Equally revealing was the observation that nearly 50 percent of the complaints data involved drivers reporting problems with anti-lock brake systems that were functioning normally, i.e., providing braking capability that is actually inferior to conventional brakes on particular road surfaces, increasing stopping distance and resulting in loss of control incidents. Furthermore, these incidents resulted in collisions some 73 percent of the time, which is consistent not only with the increase in collisions on snowy and/or slushy road surfaces, but with the need for public education about the reduced stopping capability of ABS in these conditions.

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