EFFECTIVENESS OF ANTILOCK BRAKES IN PASSENGER CARS

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At the First International Skid Conference eighteen years ago, Lister and Kemp described experiments with antilock braking for passenger cars. Subsequently a number of systems were developed and several were placed in limited production. Although both 2-wheel and 4-wheel antilock braking systems perform superbly well under treacherous driving conditions, they have not proved to be commercially successful. Several published studies are reviewed which have shown that antilock braking in automobiles has worthwhile potential for skid control and accident avoidance. An economic study of 100 skidding accidents from a randomly-selected sample of 613 insurance cases is described in detail. The benefit/cost ratios for passenger cars was estimated from the data to be 1.4 for 2-wheel antilock braking and 1.3 for 4-wheel systems, and payback periods were determined to be about 7 and 8 years respectively. The outlook for antilock brakes in passenger cars is discussed.

At the First International Skid Conference eighteen years ago, Lister and Kemp described experiments with antilock braking for passenger cars (1). By preventing the rear wheels of an automobile from locking and then skidding during a panic stop on roads slippery with water or ice, an antilock brake system installed on the rear wheels can shorten stopping distances, provide straighter stops and reduce the tendency to spin out on a curve. Furthermore, antilock systems on front wheels enable evasive steering otherwise impossible with wheel lockup. The major car manufacturers experimented with antilock braking systems in the 1960s, and in the early part of this decade they were offered as factory-installed options in a number of American luxury cars (2, 3 and 4). In spite of their functional effectiveness (5, 6 and 7), however, antilock brakes did not sell well as options in passenger cars and most have been withdrawn from the market. Apparently customers were not persuaded that their benefits justified the cost. It is the purpose of this paper to examine the effectiveness of antilock brake systems for passenger cars from an economic standpoint.

Skidding incidents are commonplace occurrences on wet city streets, icy suburban roads and on rainy highways. It has been estimated (8) that 23% of motor vehicle accidents occur on road surfaces which are wet, snowy or icy. Although it can be argued in most cases that skidding is not in itself the causative element, it unquestionably is a major aggravating factor in many motor vehicle collisions. There seemed to be considerable variability in earlier estimates of skidding involvement (9) but on the average they agree with several recent studies (10, 11 and 12) which indicate that about 15% of all reportable motor vehicle crashes probably involve skidding. What we would like to have for our present purpose, of course, are analytical estimates of the cost reduction potential of antilock brake systems in mitigating the consequences of accidents involving skidding. Several automotive manufacturers have researched the cost effectiveness of antilock brakes, but unfortunately they have not been in a position to publish their results. Only three relevant studies in the open literature have come to our attention, and unfortunately none of them consider dollar benefits. They are as follows:

1. Last year the Indiana University Institute for Research in Public Safety evaluated the accident avoidance potential of antilock braking by analyzing 89 accidents which had been intensively investigated by multidisciplinary teams. At "certain or probable levels of assuredness" it was estimated (13) that 2-wheel antilock brake systems would have prevented or reduced the severity of 1.9% of the accidents, and 4-wheel antilock braking had a 9.3% potential payoff in collision avoidance.

2. As part of the Swedish Experimental Safety Vehicle program, the accident avoidance potential of pre-crash steerability with 4-wheel antilock braking was studied in 168 police reports of locked-wheel accidents and 372 interviews with drivers of company fleet cars. It was concluded (14) that 40-50% of the collisions could have been "avoided or considerably reduced" by steering capability. Assuming the 15% skidding involvement reported above for all accidents, these Swedish results suggest an accident avoidance or severity reduction potential of about 7% for 4-wheel antilock braking (i.e., 40-50% mitigation of 15% skidding involvement).

3. In 350 skidding accidents in West Germany, HUK-Verband (German Motor Traffic Insurers) reported (15) that 4-wheel antilock braking systems would have minimized or avoided the accident with "sure benefit" in 7.1% of the cases and with "good use" in another 8.3%.

Economic Study

In order to evaluate the effectiveness of antilock braking for passenger cars, in 1972 Liberty Mutual purchased a 1971-model Chrysler equipped with the 4-wheel antilock Sure-Brake system manufactured by the Bendix Corporation. Special controls were provided so that the antilock feature could be disabled by a selector switch, operated on the rear wheels alone, or provided for all four wheels. In order to evaluate maneuverability, extensive tests were carried out on a skid pan (typical results were reported in (16)) and systematic low speed testing was conducted on actual roads under slippery conditions. On the basis of this experience and published data (2), estimates were made of the loss reduction potential of 2-wheel and 4-wheel antilock braking, as well as skilled drivers, utilizing a random sample of typical skidding accident insurance cases. These data were then subjected to economic analysis.

Case Analysis

The accident cases utilized for the study comprised an essentially random sample of approximately 10% of all the automotive accidents reported by policyholders to the Liberty Mutual office in Worcester, Massachusetts during a twelve-month period during 1970-71. That period was chosen because it was the last one prior to the adoption of no-fault automobile insurance in Massachusetts, and hence complete and detailed accident reports were available (which was not true in the years following). Every tenth accession number in the office register book was chosen. When one of these numbers was found not to represent a developed case, the next number was taken or the one after that. At 42° north latitude and about forty miles from the Atlantic ocean, Worcester has moderately severe winters with substantial amounts of snow and ice. These conditions are exacerbated for driving by many steep hills within the city and outside. The policyholder population came from 51 neighboring cities and towns (3% rural) with a total population of about 600,000. 613 cases involving 1068 automobiles were utilized. Thirty-nine of those automobile collisions involved trucks or buses, two were with motorcycles and there were eight pedestrian claims.

There were 100 skidding cases (16.4% of the total number reviewed), which were defined as those where there was evidence of slippery conditions or a driver reported skidding. Each of them was studied carefully to determine the extent to which accident severity might have been mitigated by: first, skillful drivers trained in skid control techniques; second, by 2-wheel antilock brakes; and third, by 4-wheel antilock brake systems. This was accomplished by estimating for each of the three countermeasures a discount factor by which the cost of the accident was multiplied. If a countermeasure was considered extremely effective, a multiplier of 0.1 was assigned. This had the effect of discounting the accident cost by 90%. If, on the other hand, a countermeasure was considered to have very little effectiveness, a multiplier of 0.9 was applied, which discounted the accident cost only 10%. The multipliers used were: 0.1, 0.3, 0.5, 0.7 and 0.9. For each of the five collisions wherein two cars skidded, an overall effectiveness multiplier could be selected without uncertainty. Two examiners were used for about half the cases and three examiners in about one-quarter of the determinations. Examiners almost always agreed within ± one step (0.3 or 0.7 instead of 0.5, for example), and there were only two instances of greater disagreement.

Damages awarded by the courts were disregarded in pricing the accidents, and for each case the economic loss was determined as follows. The cost of bodily injury was reckoned by adding up actual charges for medical expenses, domestic services necessitated by incapacitation, lost wages and out-of-pocket expenditures incurred because of human injury. There were no skidding cases involving deaths, and no note was taken of any monetary value ascribed to pain and suffering, deprivation of companionship, unrealized loss of potential earnings, and the like. Property losses and the cost of physical damage to vehicles other than passenger cars were taken from estimate sheets, invoices and other evidential sources. In order to provide uniform and complete pricing for the physical damage to the automobiles involved, average repair costs were used instead of the actual appraisals. These data were taken from a study (17) conducted by the American Mutual Insurance Alliance, wherein a representative body of detailed information was collected on a country-wide basis by four large auto insurers from 89,060 crash repair estimates involving 1969-1972 cars. Specific average values were employed for both collision and property damage coverages in each of twelve impact areas (front, right front corner, right front quarter and so forth), which were easy to identify in the accident records. It should be noted that this cost assignment procedure does not include any deductible (generally $50), and hence understates cost somewhat.

Benefit Determination

The total estimated cost of the 100 skidding accidents was $91,200. For 2-wheel antilock brakes the total of the discounted costs was $65,500 for a total saving of $25,700. For 4-wheel antilock brake systems the total of the discounted costs was $42,400, for a total savings of $48,800. There were 1068 automobiles involved in the 613 accidents studied, so that the average savings per car for each accident was calculated as $24 for those equipped with 2-wheel antilock brakes ($25,700 total savings/1068 cars) and $46 for cars having 4-wheel systems ($48,800/1068).

According to the National Safety Council (18), there were 23.8 million accidents reported in the United States during 1971, and the U.S. passenger car population then was 91.9 million. Based on these data it is calculated that on the average 25.9% of the passenger cars on the road in 1971 were involved in accidents. Utilizing data attributed to the R. L. Polk and Company (19), the median life of automobiles registered in the United States during 1971 was estimated (from graphs of model-year registrations) to be 10.1 years. Assuming an average involvement of 25.9% and a 10.1-year life, the lifetime expectation of 1971 cars was calculated to be 2.62 collisions. Multiplying 2.62 times the average savings for each accident which were given in the preceding paragraph, yields estimated lifetime savings of $63 (in 1971 dollars) for cars equipped with 2-wheel antilock brakes, and $120 for 4-wheel systems.

During the initial work on this project in 1971, representatives of several manufacturers of antilock brakes (in private conversations with the author) estimated that for universal application 2-wheel antilock brakes could be expected to have a sticker price in 1971 of $50, and a 4-wheel system a price of $100. Electronics are less expensive today, so that the price of antilock brakes were said by a manufacturer (in private to the author) to have increased only 20% in the ensuing five years, despite much greater inflation. 15% of the

selling price has been allowed for maintenance of the antilock brake systems over the lifetime of the automobile. With these 20% and 15% adders, the 1976 prices of antilock brakes in mass production is assumed to be $69 for a 2-wheel system and $138 for a 4-wheel system.

In order to prepare an economic analysis in a contemporary frame of reference, it is necessary to adjust antilock braking system benefits in terms of inflation on the one hand and the time value of money on the other. The inflation adjustment for the 10.1-year period from January 1976 to February 1986 was based on the actual movement of the Labor Department's Medical Care Index and Automobile Maintenance and Repair Index from 1971 to 1975 and on Chase Econometrics, Inc. forecasts (20) of these indices for 1976 through 1985. The two indices were combined by weighting medical care 40% and automobile maintenance and repair 60%, which corresponds roughly to the present distribution of injury and car damage premium. The average annual rate of inflation for the period 1971-1976 was 7.8%. For the period 1976-1985 the inflation rate was forecasted to average 7.3%. The adjustment for the time value of money was based upon a discount rate of 6%.

Results

Based on the foregoing, the results of the study are these: First, the present value of the lifetime savings of a 2-wheel antilock brake system assumed to be sold in 1976 is estimated to be about $95 and for a 4-wheel system to be approximately $180; second, the benefit/cost ratios are 1.4 for 2-wheel and 1.3 for 4-wheel antilock brake systems; and, third, the indicated payback periods are about 7 years for a 2-wheel system and 8 years for 4-wheel antilock braking.

Discussion

If the payback calculations of the preceding section were used in insurance pricing, conceivably the premium reductions for antilock systems could gradually pay back to car owners the cost of an antilock braking system. However, considering the small annual savings in insurance premiums and the 7 or 8-year payback period, the likelihood that car owners would be motivated to purchase an antilock system is questionable. Motivation would be enhanced if the payback period could be reduced to within the first 3 or 4 years of car ownership, because the resale value of safety devices is minimal.

The foregoing analysis was based on a sample. As with any results derived from a sampling procedure, the results of this study are subject to sampling error. There are potentially at least two important sources of sampling error in this study. First, the most serious potential error derives from the happenstance that the sample drawn did not include any fatalities. However, National Safety Council statistics (18) indicate a 0.22% fatality rate for automobiles reported to be involved in 1971 accidents. No adjustment was made in this study for this potential sampling error because it would have required assigning a dollar value to human life, which at best is extremely difficult to do on an objective basis. Any such correction, of course, would increase the benefits and shorten the payback. The second potential source of sampling error relates to geography. The sample was drawn from the vicinity of Worcester, Massachusetts, as described previously. Whether or not the weather, traffic conditions and driving population in Worcester are typical of North America is debatable. The analysis has made the assumption that on the average they are typical, and that Worcester, Massachusetts may be considered skid-wise to be "Middletown, North America". However, this assumption is based upon subjective judgment alone.

Concluding Remarks

Judging from the results of this study, antilock braking systems seem to be economically justified, on the average, for private passenger cars. For high-mileage and high speed driving, antilock brakes likely would be much more cost effective than average. An example would be a salesman spending 15 or more hours a week behind the steering wheel, much of it in high-speed driving where antilock brakes are a spectacularly effective countermeasure for highway skids.

However, it is difficult to be optimistic about the near future of antilock brake systems after customers have spurned them as options. Nevertheless, automotive history has examples of technological resurrection, and this study indicates that antilock braking might be a good candidate for a successful rebirth. Design improvements, cost reductions and imaginative marketing would be crucial elements in that process.

Acknowledgments

Students at the Worcester Polytechnic Institute who assisted with the testing and case reviews were Robert Guertin, John Luikey, Roland Morreau and Warren Smith. Advice on interpretation was provided by Brian O'Neil at the Insurance Institute for Highway Safety. Jack Farron, Thomas Schafer and George Hickner at the Bendix Corporation rendered valuable technical assistance. Within Liberty Mutual, instrumentation and testing was done by Donald Vaillancourt, selection of cases and examination of data folders was guided by Norman Slocum, high-cost cases were made available by Richard Shepler, the benefit/cost and payback calculations were done by Gary Countryman, the manuscript was reviewed by Fred Walter and the typing was done by Susan Munyan.

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