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# **An Evaluation of the Advance Braking Light Device**

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| 16. Abstract<br><p>This paper reports an evaluation of a new concept for providing advance warning of brake applications known as the Advance Braking Light Device (ABLD). The ABLD senses the rate at which the accelerator is released. If the rate is equal to or faster than a predetermined minimum it turns on the brake lights for one second. In this way the brake lights are energized sooner than they would be normally because the time spent moving the foot from the accelerator to the brake is saved.</p> <p>In the evaluation subjects drove three vehicles over a route in normal traffic. Measures were made of the number of brake applications, the number of brake applications equal to or less than one second, the number of ABLD actuations, the number of times the ABLD was actuated without subsequent braking, and accelerator-to-brake foot-movement time when the ABLD was actuated.</p> <p>The results of the study indicate that the ABLD functioned as intended in all test vehicles, that it would not cause a great increase in brake signal "noise" (i.e., brief, meaningless brake signals), and that it would provide an average gain in brake warning time of about 0.20-0.30 second.</p> <p>Estimates were made of the potential reductions in rear-end collisions associated with use of the ABLD, and are reported in the paper.</p> |  |   |           |
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## EXECUTIVE SUMMARY

This report describes a test run on a new concept for providing advance warning of brake applications. It is known as the Advance Braking Light Device (ABLD). The ABLD senses the rate at which the accelerator is released. If the rate is equal to or faster than a predetermined minimum it turns on the brake lights for one second. The theory is that if the driver is indeed making an "emergency" brake application, the ABLD will turn on the brake lights sooner (basically saving the time spent moving the foot from the accelerator to the brake).

An obvious interest in this study is inferring what safety benefits might come from adoption of the ABLD concept. There are two aspects of the results of this study that are of consequence in this respect. The first concerns any negative effects of the ABLD. That is, does the device cause problems that may negate or reduce its potential benefits?

The analysis of ABLD actuations not followed by a brake application was carried out to address this question. Such events could be considered "false alarms," in that an "emergency" device was actuated but there was no braking immediately afterward. However, the data from this investigation seem to indicate clearly that the occasions when the ABLD is actuated and the brakes are not applied would result in a minor addition to the number of short-duration brake light activations that are already part of the driving scene. Thus, the occasional activation of the ABLD without braking should not create problems for other drivers or diminish the effectiveness of the system.

The second question relates to the effectiveness of the system in reducing collisions. The system seems to do what it was designed to do, i.e. provide the following driver with advance warning of a brake application under conditions where that brake application is likely to be sudden and severe. Therefore, it seems reasonable that the ABLD should reduce the incidence of rear-end collisions.

## TABLE OF CONTENTS

|   |    |
|---|----|
| LIST OF TABLES .....                                  | iv |
| EXECUTIVE SUMMARY .....                               | ii |
| INTRODUCTION .....                                    | 1  |
| METHOD .....  | 2  |
| Introduction .....                                    | 2  |
| Equipment .....                                       | 2  |
| Vehicles .....  | 3  |
| Test Route .....                                      | 3  |
| Subjects .....  | 3  |
| Procedure .....                                       | 3  |
| RESULTS .....   | 5  |
| General .....   | 5  |
| Activations of the ABLD Without Braking .....         | 6  |
| Reaction Time .....                                   | 7  |
| Reduction in Accidents Associated with the ABLD ..... | 9  |
| CONCLUSIONS .....                                     | 13 |
| REFERENCES .....                                      | 14 |

## LIST OF TABLES

|  |    |
|--|----|
| 1. Mean Values of Categories for all Test Vehicles . . . . .                     | 5  |
| 2. Number of Advance Brake Applications for Each Vehicle . . . . .               | 7  |
| 3. Number of ABLD Actuations Without Braking for Each Vehicle . . . . .          | 8  |
| 4. Number of Brake Applications of one Second or Less for Each Vehicle . . . . . | 8  |
| 5. Relationship of ALBD Actuations Without Braking to $\leq 1$ Sec. Applications | 9  |
| 6. Potential Gains From Use of the CHMSL . . . . .                               | 12 |
| 7. Potential Gains From Use of the ABLD . . . . .                                | 12 |
| 8. Potential Gains From Use of the ABLD With CHMSL . . . . .                     | 12 |

## INTRODUCTION

Rear-end collisions are among the most common forms of two-vehicle crashes, accounting for about 23% of all reported accidents in 1986, according to Accident Facts, 1987. While they are not typically the form of collision most likely to cause injury to the vehicle occupants, at the very least they are costly in terms of sheet metal damage, and associated expenses.

For many years research has been directed toward finding ways to improve the rear signalling system on automobiles in an effort to better communicate between cars and reduce rear-end collisions. The field research that led to the development of the center-high-mounted stop lamp (CHMSL) suggested that the reduction in collisions associated with an effective device could be substantial.

This report describes a test run on a new concept for providing advance warning of brake applications. It is known as the Advance Braking Light Device (ABLD). The ABLD senses the rate at which the accelerator is released. If the rate is equal to or faster than a predetermined minimum it turns on the brake lights for one second. The theory is that if the driver is indeed making an "emergency" brake application, the ABLD will turn on the brake lights sooner (basically saving the time spent moving the foot from the accelerator to the brake). If the driver does not contact the brake pedal after the ABLD is actuated, the following driver will see the brake lights come on for one second. Presumably, this would be no different than many other times when the driver ahead applies his/her brakes briefly.

## METHOD

### Introduction

The purpose of this study was to measure various performance characteristics related to the ABLD operation, using different cars driven by representative drivers who were not aware of the purpose of the study. The cars were driven over a specified route, with the information being collected using special equipment.

### Equipment

Each test vehicle was equipped with the ABLD, a data collection system supplied by the ABLD developer, and (for one of the three test vehicles) a second system to collect certain additional data.

The ABLD consists of a small treadle attached to the accelerator pedal, which senses the rate at which the accelerator is released. This signal goes to a processor unit, which determines whether the brake lights should be turned on or not. In the case of these test installations, the unit was not attached to the brake lights, but instead provided information to a special data collection system.

The data collection system counted and stored information on four functions:

1. Brake applications. The number of times the brake pedal was depressed far enough to turn on the brake lights.
2. Brake applications equal to or less than one second. The total of these short brake applications was also included in item 1. Thus, subtracting the total in 2 from the total in 1 gives the number of brake applications of duration greater than one second.
3. The number of times the ABLD was actuated.
4. The number of times the ABLD was actuated and the driver did not contact the brake pedal. These were included in item 3 as well. Thus, subtracting the total in 4 from that in 3 gave the number of presumably appropriate ABLD actuations.

In addition, on one vehicle only, equipment was installed to measure the elapsed time between the actuation of the ABLD and actuation of the brake light switch by the brake pedal.

## Vehicles

Three vehicles were used in the test. These were as follows:

1. 1981 full-size station wagon, automatic transmission
2. 1988 mid-size 4-door sedan, automatic transmission
3. 1988 mid-size 2-door sedan, 4-speed manual transmission.

## Test Route

A route was laid out on roads in an urban area. The route covered 14.5 miles. On that route the subject encountered 43 traffic signals, four stop signs, one yield sign, and one yellow-flasher signal. The route went through areas that would expose the subject to a variety of driving conditions, including dense downtown traffic, and areas where there were large numbers of pedestrians. Speed limits ranged from 25 to 45 mph. It typically took about 40–45 minutes to complete the trip.

## Subjects

Subjects were licensed drivers of both sexes and various ages. A total of 29 subjects participated in the study with the automatic transmission vehicles. Full data on both cars were obtained from 25. A different group of 17 subjects participated in the study with the manual transmission car.

## Procedure

The two automatic transmission cars were run first. Subjects were run in pairs. They reported to the Institute, signed a consent form, and were read the instructions. In the instructions they were told that they should drive the car as they would normally over the route shown on a map in the vehicle. They were also told that data would be collected during the trip, but that it would not affect vehicle operation. They were not told what data were being collected until their participation was complete. After any questions had been answered, they left on the first run. When they returned the data were recorded, the counters reset, the subjects switched cars, and started the second run. In this way complete data were obtained from 25 subjects.

The manual transmission car was run next, and a new group of 17 subjects was utilized. The general procedure, instructions, and route were the same as in the case of the automatic transmission cars.



For about half of the subjects an additional short run was made in which they were asked to release the accelerator and tap the brake pedal as fast as possible on a given signal. This was done about five times for each subject. Foot movement times were recorded.

## RESULTS

### General

The general results of this study are summarized in Table 1. This table shows the mean number of times each of the four functions discussed earlier occurred on the standard trip for each vehicle. In comparing the automatic and manual transmission cars, it must be remembered that they were driven by different subjects, so the differences may reflect people effects to an unknown extent.

TABLE 1  
MEAN VALUES OF CATEGORIES FOR ALL TEST VEHICLES

| Categories                         | Vehicles        |                    |                 |
|------------------------------------|-----------------|--------------------|-----------------|
|                                    | Large Automatic | Mid-Size Automatic | Mid-Size Manual |
| Brake Applications                 | 123.1           | 69.4               | 218.6           |
| Brake Applications $\leq$ 1 second | 37.2            | 8.2                | 138.2           |
| ABLD Activated                     | 3.8             | 8.5                | 1.5             |
| ABLD Activated Without Braking     | 1.2             | 1.9                | 0.7             |

In examining Table 1 it is apparent that there are large differences among the three cars in the number of brake applications, and brake applications equal to or less than one second. The mean number of times the ABLD was actuated also varies considerably, from a minimum of 1.5 times in the mid-size manual transmission car to 8.5 times in the mid-size automatic transmission car. There is also some variability in the number of ABLD actuations without braking. However, these functions were infrequent in any case, and certainly so in comparison to brake applications equal to or less than one second.

The differences among vehicles noted in Table 1 were much larger than expected. It is not clear why they came about, although there were some physical differences among

the vehicles that may offer a partial explanation. For example, the large automatic car had an overdrive transmission, and did not slow down as much as did the mid-size automatic when the accelerator was released. This may account for the greater number of brake applications in the large, as compared with the mid-size automatic vehicle. The mid-size manual vehicle was a sportier car than the other two, and it is possible that the subjects tended to drive it harder than the other two vehicles.

The differences in the mean number of ABLD actuations are more difficult to explain. One of the reasons for running the manual transmission vehicle was a concern that the more frequent accelerator releases associated with shifting gears may produce a higher incidence of ABLD actuations without braking. Clearly, this was not the case. However, there is no obvious reason that may explain the differences in the frequency with which the ABLD was actuated from one vehicle to another.

Table 2 shows the frequency with which the ABLD was actuated during the test trip with the three vehicles. For example, seven subjects in both the large automatic and mid-size automatic vehicle recorded no actuations of the ABLD during the test trip. There is considerably greater variability with the automatic transmission cars; however, this may be at least partially attributable to people differences. For both the large automatic transmission car and the mid-size manual transmission car the most frequent number of actuations was zero. For the mid-size automatic transmission car, the most frequent number of actuations was two. There is no obvious reason for this difference. It may be associated with the placement of the ABLD treadle, the performance characteristics of the vehicles, or other reason(s) not apparent to the investigator.

#### Activations of the ABLD Without Braking

The distribution of the number of ABLD actuations without braking recorded for each car is shown in Table 3. For both the large automatic transmission and mid-size manual transmission cars the most frequent number of such actuations per subject was zero. For the mid-size automatic transmission car it was one.

Actuations of the ABLD without braking would be of concern if they greatly increased the number of times the brake lights of the car were briefly illuminated. Table 4 shows the number of brake applications of one second or less recorded for each vehicle. There were great differences among vehicles. Brief brake applications were relatively infrequent in the case of the mid-size automatic, more frequent with the large automatic, and much more frequent with the manual-transmission vehicle.

TABLE 2  
NUMBER OF ADVANCE BRAKE APPLICATIONS FOR EACH VEHICLE

| Number | Large Automatic | Mid-Size Automatic | Mid-size Manual |
|--------|-----------------|--------------------|-----------------|
| 0      | 7               | 2                  | 7               |
| 1      | 2               | 1                  | 4               |
| 2      | 4               | 7                  | 2               |
| 3      | 3               | 5                  | 1               |
| 4      | 1               | 1                  | 1               |
| 5      |                 |                    | 2               |
| 6      | 3               |                    |                 |
| 7      | 2               | 1                  |                 |
| 8      | 1               | 2                  |                 |
| 9      |                 | 3                  |                 |
| 10     | 2               |                    |                 |
| 11     | 1               | 1                  |                 |
| 12     |                 | 2                  |                 |
| 13     |                 |                    |                 |
| 14     | 1               |                    |                 |
| 15     |                 |                    |                 |
| 16     |                 |                    |                 |
| 17     |                 | 2                  |                 |
| 18     |                 |                    |                 |
| 19     |                 |                    |                 |
| 20     |                 |                    |                 |
| >20    |                 | 3                  |                 |

Table 5 shows the relationship of such actuations to brake applications of one second or less. In 72% of the runs made as part of this test the number of ABLD actuations without braking was no more than 10% of the number of voluntary brake applications having a duration equal to or less than one second. In 98% of the runs they were equal to no more than 40% of these brief brake applications.

Reaction Time

Foot-movement times measured from the actuation of the ABLD until the normal brake light switch was closed ranged from 0.23 to 0.77 second in that portion of the study run in normal traffic. Interestingly, this corresponds closely to the foot-movement times recorded by Olson et al. (1984) in a study of perception-response time of drivers to an unexpected roadway hazard. The 5th and 95th percentile values resulting from that study were 0.25 and 0.74 second respectively.

TABLE 3

## NUMBER OF ABLD ACTUATIONS WITHOUT BRAKING FOR EACH VEHICLE

| Number | Large Automatic | Mid-Size Automatic | Mid-size Manual |
|--------|-----------------|--------------------|-----------------|
| 0      | 11              | 6                  | 10              |
| 1      | 6               | 9                  | 4               |
| 2      | 3               | 6                  | 2               |
| 3      | 2               | 2                  | 1               |
| 4      | 1               | 3                  |                 |
| 5      |                 | 1                  |                 |
| 6      | 1               | 1                  |                 |
| 7      |                 |                    |                 |
| 8      |                 |                    |                 |
| 9      |                 |                    |                 |
| 10     |                 |                    |                 |
| >10    |                 | 1                  |                 |

TABLE 4

## NUMBER OF BRAKE APPLICATIONS OF ONE SECOND OR LESS FOR EACH VEHICLE

| Number | Large Automatic | Mid-Size Automatic | Mid-Size Manual |
|--------|-----------------|--------------------|-----------------|
| 0-9    | 0               | 17                 | 0               |
| 10-19  | 7               | 6                  | 0               |
| 20-29  | 3               | 1                  | 0               |
| 30-39  | 6               | 1                  | 0               |
| 40-49  | 5               | 0                  | 1               |
| 50-59  | 3               | 0                  | 0               |
| 60-69  | 0               | 0                  | 1               |
| 70-79  | 0               | 0                  | 1               |
| 80-89  | 0               | 0                  | 2               |
| 90-99  | 0               | 0                  | 1               |
| 100+   | 1               | 0                  | 11              |

There is no way of knowing how many of the ABLD actuations recorded in the field study represented responses to perceived emergency situations. In a very straightforward emergency situation, where the danger was readily apparent and the only response option

TABLE 5

RELATIONSHIP OF ABLD ACTUATIONS WITHOUT  
BRAKING TO  $\leq 1$  SEC. APPLICATIONS  
(5 or more of latter)

| Category    | Cumulative<br>Percent |
|-------------|-----------------------|
| $\leq 10\%$ | 72                    |
| 11-20%      | 88                    |
| 21-30%      | 97                    |
| 31-40%      | 98                    |
| 41-50%      | 98                    |
| 51-60%      | 100                   |

was to hit the brake, foot-movement times would probably tend toward the low end of the distribution. It was for this reason that the follow-up response data were taken. It will be recalled that in this portion of the test subjects drove the car and, on command from the experimenter, released the accelerator and tapped the brake pedal as quickly as possible. The times recorded in this investigation ranged upward from 0.16 second. In a portion of the Olson et al. study that was conducted in the same way, the 5th and 95th percentile foot-movement times were 0.10 and 0.28 second respectively. These analyses suggest that a conservative estimate of the typical improvement in warning to following drivers achieved through use of the ABLD under emergency conditions would be about 0.20 second. Based on the reaction times recorded in the field portion of the study, it may be more than that. In the analyses to follow, calculations will be based on improvements of 0.20, 0.25, and 0.30 second.

#### Reduction in Accidents Associated with the ABLD

An obvious interest in this study is inferring what safety benefits might come from adoption of the ABLD concept. There are two aspects of the results of this study that are of consequence in this respect. The first concerns any negative effects of the ABLD. That is, does the device cause problems that may negate or reduce its potential benefits?

The analysis of ABLD actuations not followed by a brake application was carried out to address this question. Such events could be considered "false alarms," in that an "emergency" device was actuated but there was no braking immediately afterward. However, the data from this investigation seem to indicate clearly that the occasions when

the ABLD is actuated and the brakes are not applied would result in a minor addition to the number of short-duration brake light activations that are already part of the driving scene. Thus, the occasional activation of the ABLD without braking should not create problems for other drivers or diminish the effectiveness of the system.

The second question relates to the effectiveness of the system in reducing collisions. The system seems to do what it was designed to do, i.e. provide the following driver with advance warning of a brake application under conditions where that brake application is likely to be sudden and severe. Therefore, it seems reasonable that the ABLD should reduce the incidence of rear-end collisions.

The measure of system effectiveness that comes from this study is improvements in warning time. As noted earlier, the data suggest that this gain would probably be not less than 0.20 second, and may be more. The question is, does this improvement translate to a reduced number of collisions, and if it does, what is the extent of the reduction?

Care must be used in inferring from reductions in response time to reductions in collisions. For many years investigators conducted studies of various concepts in rear signalling systems, using a response time criterion. One of the systems that showed promise, separated function, was used in the field evaluation carried out in the original Essex study (Malone, et al, 1978), and was not associated with a significant reduction in rear-end collisions. Hence, the fact that one can measure a response time improvement under the conditions of a controlled test does not necessarily mean that the subject system will reduce collisions.

Of course, the response time gains that have been measured in various studies are attributable to improvements in conspicuity and/or reductions in ambiguity. The signal did not actually come on sooner, as with the ABLD. The center, high-mounted stop lamp (CHMSL) has been shown in several studies to bring about a very large reduction in rear-end collisions. Its effectiveness is almost certainly due to the fact that it is close to the normal fixation point of following drivers, and it signals a brake application and nothing else. Both of these factors should reduce the overall response time of following drivers who are presented with a brake signal.

Recognizing this fact, there have been some attempts to measure the response time gain provided by the CHMSL. It must be borne in mind that these tests were carried out under conditions where there was virtually no chance of the subject vehicle colliding with the vehicle presenting the signal. Therefore, there is no assurance that the response times measured are truly indicative of those that would apply under more threatening conditions.

That caveat aside, the results of these tests (Allen Corp, 1978; Sivak et al., 1981) suggest that the CHMSL may reduce following driver response time by an average of 0.30 to 0.35 second, under those conditions where it has any effect at all.

If, in addition to the natural benefits of the CHMSL, the use of a device such as the ABLD gives the following driver an average of about 0.20–0.30 second additional warning under emergency conditions, it seems reasonable that there should be further reductions in rear-end collisions. How much of a reduction depends on the relationship between time and collision probability, something that is not known with any accuracy at present. The analysis that follows is an estimate based on available data, and (important to note) a number of assumptions that may or may not be correct.

Probably the best method for estimating the potential effects of the ABLD is to work from data on the CHMSL. The data on the CHMSL suggest a reduction in rear-end collisions of about 50%. The analysis provided by Malone, et al. (1978) suggests that, at that level, the use of the CHMSL would prevent about 1.7 million accidents/year, and produce a savings of about 730 million dollars/year, as shown in Table 6.

Based on these data, Tables 7 and 8 have been prepared in the same format. Table 7 provides estimates of gains resulting from use of the ABLD alone for three response time gains ranging from 0.20 to 0.30 second. Table 8 is identical to Table 7 except it considers the ABLD in combination with a CHMSL.



TABLE 6

POTENTIAL GAINS FROM USE OF THE CHMSL<sup>1</sup>  
(Malone, et al., 1978)

| Gain in Response Time (seconds) | Percent Reduction in Rear-End Collisions | Reduction in Collisions (thousands) | Monetary Savings (in millions of 1978 dollars) |
|---------------------------------|--|-------------------------------------|--|
| 0.3                             | 50                                       | 1700                                | 730  |

TABLE 7

POTENTIAL GAINS FROM USE OF THE ABLD<sup>2</sup>  
(w/o CHMSL<sup>2</sup>)

| Gain in Response Time (seconds) | Percent Reduction in Rear-End Collisions | Reduction in Collisions (thousands) | Monetary Savings (in millions of 1978 dollars) |
|---------------------------------|--|-------------------------------------|--|
| 0.20                            | 34                                       | 1134                                | 500  |
| 0.25                            | 42                                       | 1418                                | 616  |
| 0.30                            | 50                                       | 1700                                | 730  |

TABLE 8

POTENTIAL GAINS FROM USE OF THE ABLD<sup>2</sup> WITH CHMSL<sup>3</sup>

| Gain in Response Time (seconds) | Percent Reduction in Rear-End Collisions | Reduction in Collisions (thousands) | Monetary Savings (in millions of 1978 dollars) |
|---------------------------------|--|-------------------------------------|--|
| 0.20                            | 51                                       | 1701                                | 750  |
| 0.25                            | 63                                       | 2127                                | 924  |
| 0.30                            | 75                                       | 2550                                | 1095   |

1 Assumes CHMSL reduces rear-end collisions by 50%.

2 The ABLD will be effective in reducing all types of vehicle rear end accidents.

3 All data for passenger cars only.

## CONCLUSIONS

This report describes an evaluation of a device (the ABLD) that speeds up the actuation of the brake signal under conditions likely to represent an emergency situation. The results indicate that the device functions as intended when installed on several types of vehicles and driven in urban traffic by ordinary drivers. There is nothing about the operation of the device to lead one to believe that it will cause problems for other drivers or diminish its effectiveness.

The ABLD, when activated, turns on the brake light an average of about 0.20–0.30 second sooner than would typically be the case. Combined with the center high-mounted brake lamp, the ABLD would appear to be a significant safety device that would reduce the incidence of rear-end collisions. Further research on its effectiveness seems clearly warranted. This work should take the form of a fleet study, measuring actual crash reduction.

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