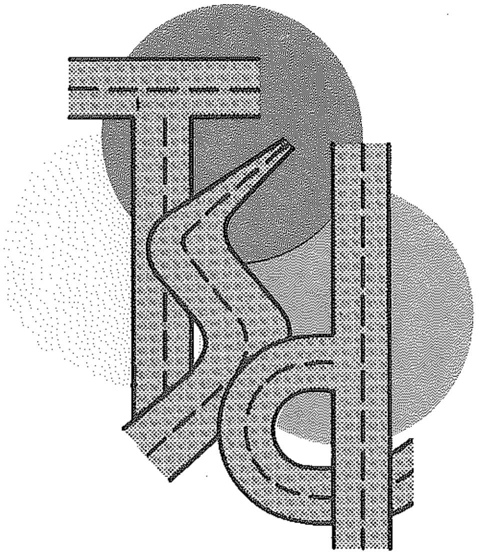
An Evaluation of Concrete Median Barrier in Michigan

TSD 531-83



TRAFFIC and
SAFETY
DIVISION

MICHIGAN
DEPARTMENT OF TRANSPORTATION

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Disclaimer

ABSTRACT

The accident experience before and after concrete median barrier (CMB) installations on Michigan roadways was examined in terms of accidents/mile, percentage of total accidents, severity ratio, single vehicle and multivehicle accidents, and fatal accidents. The effects of various roadway characteristics (i.e. alignment, shoulder slope, glare screen, curb/shoulder type, ADT, and lanes) on the number of injury and fatal CMB accidents were investigated. Finally, the effect of vehicle weight class on CMB accident severity was investigated.

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BACKGROUND

The safety benefits of guardrail and median barrier have been the subject of many studies. Generally, it has been found that fatal accidents remained the same or decreased slightly after barrier installation, and that injury and property damage accidents increased substantially. 1/ The decrease in fatal accidents was due to the reduction of cross-median accidents which, according to a 1958 California study, 2/ accounted for 19 percent of all fatalities on freeways in a three-year period. The increase in injury and property damage accidents was attributed to the median barrier being "...a fixed-object struck by out-of-control vehicles that might have recovered without incident if the barrier had not been installed." 3/

Concrete median barrier (CMB) replaced the traditional steel beam guardrail on many sections of highway during the last few years. CMB is virtually maintenance-free compared to steel beam guardrail. Also, the shape of CMB is designed to cause less property damage than steel beam guardrail accidents and more safely redirect vehicles which leave the road. A 1979 Michigan study 4/ assessed whether snow accumulation along CMB installations was a problem. The author concluded, from analysis of winter accident data for 1971/72 through 1975/76 and a survey of district traffic and maintenance engineers, that accumulated snow along CMB did not present a hazard to motorists. Ten rollover and six cross-median accidents occurred in that five-winter study period. These 16 accidents were seven percent of total CMB accidents and no fatalities were involved. The study also noted that six of the ten rollover accidents involved "compact" cars.

Many experimental crash tests have been conducted with CMB to determine which barrier shape would permit drivers to regain control of their vehicles after striking the barrier and return to the roadway with a minimum of damage. A report published by the Federal Highway Administration in 1976 5/ recommended use of the New Jersey shape. It was based on standardized crash tests performed on the New Jersey and GM shapes using various vehicles ranging in size from a compact car to an intercity bus.

A British study conducted in 1977 6/ crashed a European subcompact car and a bus into various CMB shapes. The results also indicated the superiority of the New Jersey shape.

Accident experience before-and-after installation of CMB is not well documented. Early studies of the effectiveness of CMB in New Jersey 7/ 8/ reported dramatic reductions in injury and fatal accidents after installation. 9/ A study of various safety improvements on approximately five miles of I-75 in northern Kentucky found New Jersey-type CMB to be effective in reducing the overall accident rate. 10/ Two preliminary accident studies 11/ 12/ were done in Michigan; however, both studies were inconclusive.

INTRODUCTION

The first standard plan for CMB in Michigan was approved by the Department of Transportation on May 30, 1974. CMB had been used, however, with various modifications as a special detail since late 1970.[13] Since then, the use of CMB has increased from 89 miles in 1976 to approximately 140 miles by 1979.

The majority of CMB along Michigan's freeway system was installed prior to 1976 and is the GM-type shape. Since May, 1976, only New Jersey-type has been installed on the state's freeways. This shape has a slightly steeper top face than the GM-type and was found to perform better in small car contacts.[14]

The median width of the study cross sections was unknown. Medians with CMB installed are less than 36-feet wide. Typically, CMB is used only where median width is less than 30 feet. For medians 30 to 60 feet wide, steel beam guardrail is normally used if a median barrier is required. Concrete glare screen is used on CMB where headlight glare may prove distracting.

This study attempts to evaluate the relationship between CMB installation and accident severity (injury and fatal accidents) and between CMB accident severity and roadway alignment, shoulder characteristics, glare screen, average daily traffic, lanes, and vehicle size. Specifically, the study seeks to answer the following questions:

1. How does CMB accident severity compare with the "before" period accident severity on roadways where CMB has replaced guardrail or grass median?
2. Are there more secondary collisions (i.e. vehicles striking other vehicles after contacting the median barrier) when CMB replaces guardrail?
3. Does fatal accident experience change when CMB is installed in place of guardrail or grass medians?
4. Are there any roadway or traffic characteristics which have a particular influence on CMB accident severity?
5. Does vehicle weight influence CMB accident severity?

The answers to these and several other questions which arose in the course of the study are detailed in the Conclusions section on pages 12-14.

PROCEDURE

CMB projects were located using the Construction Division's computer files. The locations from this file were verified using the two preliminary CMB studies [11] [12] and the department's photolog.

The photolog was also used to gather the following information concerning the roadway and CMB:

1. Beginning and Ending Mileages.
2. Horizontal Alignment.
3. Shoulder Slope.
4. Glare Screen Presence and Type.
5. Curb Type/Shoulder Width.
6. Number of Lanes (one direction).
7. "Before" CMB Condition (Since the first photolog inventory was completed in 1974/75 the "before" condition was unavailable for CMB segments installed prior to 1975. These 43 segments totalled 48 miles.)
    a. Grass
    b. Guardrail (The guardrail type was unknown. An analysis of the relative performance of the various guardrail types was beyond the scope of this study.)

CMB installation dates were obtained from Construction Division records. It was not possible to determine the CMB shape (i.e. New Jersey or GM) from the photolog. Since prior work using crash tests has demonstrated the relative merits of the various CMB shapes, a further evaluation using accident data would contribute little new information.

Accident experience was obtained for the following three groups:

1. Group I (30 miles) had steel beam guardrail median barrier prior to CMB installation. The locations in this group had CMB installed in 1975 or later.
2. Group II (18 miles) had grass median with no barrier prior to CMB installation. The locations in this group had CMB installed in 1975 or later. About 50 percent of the mileage had an additional lane in each direction added on the median side of the roadway at the time CMB was installed. Hence the median was considerably narrowed.
3. Group III (94 miles) consisted of the locations in Groups I and II and additional segments with CMB installed as early as 1974 for which the "before" period median treatment was unavailable from the photolog. Reviewing the construction plans to obtain this information would not provide compatible milepoints for obtaining accident experience.

ACCIDENT EXPERIENCE

The actual numbers of guardrail and CMB accidents were not of central concern in this analysis. The likelihood of a collision resulting in an injury or fatality was what this study attempted to assess. Accident occurrence is strongly influenced by median width, an analysis of which was beyond the scope of this study. In addition, the problem of unreported accidents adds uncertainty to accident numbers. (See reference 11 for an attempt to analyze the unreported accident problem and reference 1 for a median barrier collision probability model.) Severity ratios were used to reflect changes in the number of injury and fatal accidents before and after the CMB installations. It was still instructive, however, to examine the history of total accidents and total guardrail and CMB accidents at the study locations.

The somewhat unconventional term of "accidents per mile" was used to relate accidents to the number of miles of barrier. Traditional accident rates (per 100 MVM) would have been highly variable since the study locations were short segments of urban freeways with variable ADTs. In addition, the number of lanes was variable. The distribution of traffic across lanes may influence accident occurrence since many barrier accidents were caused by improper lane changes.

Although ADT on two roadway segments doubled between 1971 and 1981, the typical increase was much less, with some segments experiencing lower volumes. The overall change for all study segments from 1971 to 1981 was an increase of three percent.

Total Accidents - For Group I, total accidents increased from 22 accidents per mile in 1971 to a peak of 92 in 1976. The number declined to 50 accidents per mile in 1981. The Group II rate showed a similar trend with peaks in 1973 and 1977 of 21 and 18, respectively. The rate then declined to a low of 11 accidents per mile in 1981. The differences between Groups I and II may have been due to differences in median width since those medians without barriers were generally wider; however, about one-half of the Group II mileage had considerably narrower medians after CMB installation since additional lanes were built within the median. Many factors may influence the difference in rates between groups, and a detailed discussion of these factors was beyond the scope of this report.

An attempt was made to model total accident experience by a straight line. A regression analysis was performed with total accidents as the dependent variable and time the independent variable. The calculated line accounted for only 0.7 percent of the variance in total accidents. The conclusion was that the total accident experience at the study locations for the period 1971-1981 could not be modelled by a single increasing or decreasing straight line.

Guardrail and CMB Accidents

Left-side guardrail accidents in Group I (steel beam guardrail in the median initially) averaged 2.7 per mile per year in the period before CMB installation (1971-1975). CMB accidents in Group I averaged 4.5 per mile per year in the "after" period (1976-1981).

A Group II (grass medians in the "before" period) accident type corresponding to barrier-related accidents was the head-on and sideswipe-opposite direction accident which averaged 0.6 per mile per year in the period before CMB installation (1971-1975). Total CMB accidents in Group II averaged 1.7 per mile per year in the "after" period (1976-1981).

The complete data are shown in Table A of the appendix. Several irregularities were apparent. A small number of left-side guardrail accidents occurred in the Group I "after" period. These were presumed to involve guardrail around bridge piers, etc., and/or coding errors. They numbered about 0.8 accidents per mile. Secondly, head-on and sideswipe-opposite direction accidents should have included all cross-median barrier accidents. A check of accident reports indicated they did not. They included miscellaneous accidents involving vehicles losing trailers, wheels, tires, etc. These numbered about 0.3 accidents per mile. Presumably, when median barriers are absent, such as in Group II, the cross-median accidents are included in this category.

Table A also shows the percentage of total accidents that were median barrier related for the study groups for each year. Four things were apparent:

1. The percentage of accidents involving the median or median barriers was low. Rear-end accidents, in comparison, accounted for an average of 61 percent of Group I accidents and 42 percent of Group II accidents.

2. For Group I the 1981 <u>CMB</u> accident percentage was similar to the 1971-72 <u>guardrail</u> accident percentage.

3. Group II, despite having fewer CMB accidents per mile than Group I, had a similar percentage of CMB accidents in 1981.

4. For Group II, the head-on and sideswipe-opposite direction accident percentage showed a sharp decline in 1976 as CMB was installed.

<u>Severity Ratio</u>: (The ratio of injury and fatal accidents to total accidents.) The Group I severity ratio for left-side guardrail accidents in the period before CMB installation was 0.37. The severity ratio for <u>CMB</u> accidents in the "after" period was 0.47.

For Group II, the severity ratio for head-on and sideswipe-opposite accidents in the period before CMB installation was 0.57*. The severity ratio for CMB accidents in the "after" period was 0.43.

None of these differences was significant at the 95 percent confidence level based on the log - likelihood test (see appendix).

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* The "after" period head-on and sideswipe-opposite severity ratio was also 0.57; however, this figure was based on a sample of seven accidents, whereas the "before" period severity ratio was based on 30 accidents. The severity ratio further confirmed that many of these were not the high severity accident expected from a head-on, or sideswipe-opposite direction collision.

The analysis of severity ratio was complicated by the problem of unreported accidents. A 1973 study [15] indicated that less than half of CMB collisions result in reported accidents. This would tend to distort the severity ratio of CMB accidents making it as much as twice as high. (For example, with 44 injury accidents out of 100 reported accidents the severity ratio is 0.44. However, if there were an additional 100 unreported noninjury accidents the true severity ratio would be 0.22). It was assumed that guardrail accidents were more likely to be reported since the vehicle was less likely to be driveable.

Because of the unreported accident problem, the number of injury and fatal accidents per mile per year was analyzed to provide information concerning the effects of CMB installation beyond an analysis of the severity ratio. With injury and fatal accidents, the problem of unreported accidents was greatly reduced since it was assumed that the nonreported accidents seldom involved injuries. Table 1 shows the changes in the number of injury and fatal accidents per mile per year between the "before" and "after" periods. (Three segments in Group I with only two years of before and after data were extrapolated to three years.) The changes in injury and fatal accidents on Michigan freeways (Interstate and U.S.) were used as controls to estimate the expected "after" values.

TABLE 1

Injury and Fatal Accidents/Mile/Year

Group I: Guardrail in "Before" Period

	Before	After	
		Observed	Expected
Left-side, Guardrail	1.03	--	1.02
CMB	--	2.09	

Group II: Grass Median in "Before" Period

	Before	After	
		Observed	Expected
Head-on & SS-OP	0.31	0.09	0.30
CMB	--	0.77	

Analysis of the injury and fatal accidents per mile per year implied similar conclusions to those from the analysis of severity ratios. For Group I, injury and fatal accidents occurred about twice as frequently with CMB than expected with guardrail. For Group II, it is important to note that the number of head-on and sideswipe-opposite injury and fatal accidents per mile, per year dropped to a quarter of the expected value when CMB was installed.

Single Vehicle/MultiVehicle Accidents - Secondary collisions (i.e., those involving a vehicle striking a barrier, then striking other vehicles) have been a concern where CMB has been installed. A comparison of the percentage of multivehicle accidents with guardrail and with CMB indicated CMB did not increase the percentage of secondary collisions. Analyzing Group III, it was found that multivehicle accidents were 10.6 percent of left-side guardrail accidents. Multivehicle injury and fatal accidents were 17.3 percent of left-side guardrail injury and fatal accidents. In comparison, multivehicle accidents were 8.8 percent of CMB accidents. Multivehicle injury and fatal accidents were 9.5 percent of the CMB injury and fatal accidents. The differences in both barrier accidents and injury and fatal accidents were not significant at the 95 percent confidence level when the data for each segment were compared using the paired t-test.

Fatal Accidents - There were 16 fatal single-vehicle accidents and 12 fatal multivehicle accidents involving left-side guardrail at the 49 locations in Group III from 1971 through 1981. There were four CMB fatal accidents at the same locations after CMB installation, all of them single-vehicle accidents.

Table 2 shows the number of left-side guardrail fatal accidents, CMB fatal accidents, and the number of fatal head-on and sideswipe-opposite direction accidents for the Group III roadways from 1971 through 1981. Also shown are the number of barrier related and nonbarrier-related fatal accidents.

TABLE 2

Fatal Accidents

Year	Left-Side Guardrail	CMB	Head-On SS-OP	Barrier Related	Nonbarrier Related	Barrier/ Nonbarrier
1971	5	-	4	9	25	0.36
1972	3	-	11	14	23	0.61
1973	8	-	1	9	33	0.27
1974	7	-	4	11	27	0.41
1975	2	0	2	4	18	0.22
1976	3	0	0	3	15	0.20
1977	0	0	1	1	7	0.14
1978	0	0	2	2	15	0.13
1979	0	0	0	0	12	0
1980	0	1	1	2	9	0.22
1981	0	3	0	3	11	0.27
Total	28	4	26	58	195	0.30

The average barrier/nonbarrier accident ratio for 1971-1976 (i.e. the period before widespread CMB use) of 0.35 was used to predict an expected number of barrier-related fatal accidents (68), that would have occurred if CMB had not been installed. The actual number of barrier-related fatal accidents was 58. This gives a reduction of 10 fatal accidents or 15 percent. This difference was tested for statistical significance using the Kolmogorov-Smirnov test (see appendix) and was significant at the 95 percent confidence level.

The use of nonbarrier fatal accidents to predict an expected number of barrier-related fatal accidents was complicated by the fact that other programs were instituted on these freeways during the study period which may have substantially reduced total fatal accidents. Examples of these are the "Yellow Book" programs to reduce roadside obstacles and the relocation of light poles from the right side of the roadway to the median on top of the CMB.

The left-side accidents in Group I when guardrail was replaced by CMB increased by 40 percent. Injury accidents doubled, and fatal accidents decreased from 11 to zero between the three-year period before CMB installation and the three years after.

The head-on and sideswipe-opposite direction accidents in Group II showed reductions of 77 percent in total accidents, 71 percent in injury accidents, and from three to zero in fatal accidents between the periods of three years before CMB installation and three years after. In addition, there were no fatal CMB accidents of any type in Group II in the three-year "after" period.

The evidence pointed to a reduction of fatal barrier-related accidents when CMB was installed, although it is difficult to assess the true contribution of CMB.

Roadway Characteristics Model - A multiple regression analysis was performed to determine which roadway characteristics, if any, contributed to CMB injury and fatal accidents. Accident experience from 1976 through 1980 for CMB installed after 1974 was used as the data file for the regression analysis. Dummy variables were used to express the nominal scale data (i.e. "either/or" data) in a form suitable for regression analysis. The roadway characteristics incorporated in the analysis were: alignment, shoulder slope, absence of glare screen, curb type, ADT, and the number of roadway lanes. The overall equation (see the complete analysis in the appendix) accounted for a total of 21 percent of the variance in CMB injury and fatal accidents. This indicated that other factors (vehicle speed, driver and vehicle characteristics, etc.) had a greater influence upon injury and fatal CMB accidents than roadway characteristics.

This analysis indicated, however, each factor's relative contribution to injury and fatal CMB accidents. Table 3 shows the roadway characteristics and the percentage of the variance associated with each characteristic.

TABLE 3

Variable	Total R-Square (%)	Incremental R-Square (%)
Average ADT	13.4	13.4
Shoulder 7-13 feet w/Valley Gutter	15.6	2.2
Absence of Glare Screen	16.8	1.2
Roadway Alignment - Curve	17.7	0.9
Shoulder ≥ 13 feet w/Rolled Curb	18.4	0.7
Positive Shoulder Slope	20.6	2.2
Shoulder 7-13 feet w/o Curb - w/Negative Shoulder Slope	20.6	0.0
Number of Lanes	20.6	Too small to be computed

ADT was the most important of the studied roadway characteristics associated with injury and fatal CMB accidents (i.e., the higher the ADT, the more injury and fatal CMB accidents which occurred). The remaining characteristics appeared to have little influence, and the number of lanes had none. Based solely on injury and fatal accidents, this analysis indicates that a barrier treatment consisting of a 7-13 foot shoulder without curb and with a negative shoulder slope was preferred.

Cross-Median and Rollover Accidents - A study conducted in Milwaukee, Wisconsin[16] categorized 170 accidents which occurred in a one-year period with GM shape CMB as follows:

14% returned to traffic lane.
4% returned to traffic lane and had a secondary collision.
5% struck the barrier and rolled over. (75% small vehicles)
7% mounted the barrier.
3% crossed the barrier and entered opposing lanes.
67% struck the barrier and remained on the shoulder adjacent to the barrier.

Only injury and fatal CMB accident reports for 1980 and 1981 were screened to determine the number of cross-median and rollover accidents. It was assumed that very few rollover or cross-median accidents occurred that would not result in an injury or a fatality. The results are shown in Table 4. Six and one half percent of injury and fatal CMB accidents were rollovers. The percentage that mounted the barrier but did not cross was 0.6 percent and those that crossed the barrier accounted for 1.3 percent. The rollover data in Table 4 also indicated that small cars (under 2,500 lbs.), although a smaller percentage than in the Wisconsin study, were still over-represented in rollovers when compared to 1981 Michigan registration percentages. The significance of the difference between expected (registrations) and observed results was tested using the Chi-Square test and the difference was statistically significant at the 95 percent confidence level. The major contributor to the Chi-Square value was the "under 2,500 lbs." class. (See appendix.)

The six cross-median accidents occurred at three segments which had concrete glare screen, two segments which had green post glare screen and one segment which had no glare screen. This evidence, combined with the results of the analysis of roadway characteristics presented previously, indicates that glare screen has little benefit in reducing cross-median accidents. However, a prior department study[17] has shown glare screen to be effective in assisting drivers in performing their visual task and to have a positive influence in reducing accidents related to driver attention to opposing traffic.

TABLE 4

1980-1981 Injury and Fatal Accidents

Vehicle Size	Cross-Median	Mounted Barrier	Rollover (%)	1981 Registrations
Passenger Cars				
Under 2500 lbs.		1	9 (30.0)	16.1
2500-3500 lbs.	1		10 (33.3)	39.0
Over 3500 lbs.	3	1	7 (23.3)	35.5
Truck	1		4	
Truck Tractor (Semi)	1		(13.4)	9.4
Bus		1		
Total	6	3	30	

CMB Accidents and Vehicle Size

Data on the size of vehicles involved in CMB collisions were available from 1978 through 1981. Table 5 shows the number of CMB single-vehicle accidents and the severity ratio by passenger car size for the four-year period.

TABLE 5

CMB (Single-Vehicle) Accidents/Severity Ratio

Passenger Car Size	1978	1979	1980	1981	Total
Less than 2500 lbs.	30/0.43	32/0.47	38/0.66	63/0.52	163/0.53
2500 to 3500 lbs.	111/0.53	134/0.51	136/0.51	183/0.52	564/0.52
Greater than 3500 lbs.	265/0.54	368/0.50	449/0.53	223/0.57	1305/0.53

Table 6 shows the same data for CMB multivehicle accidents.

TABLE 6

CMB (Multivehicle) Accidents/Severity Ratio

Passenger Car Size	1978	1979	1980	1981	Total
Less Than 2500 lbs.	7/0.29	5/0.60	7/0.75	10/0.70	29/0.55
2500 to 3500 lbs.	11/0.73	14/0.57	17/0.53	25/0.56	67/0.58
Greater than 3500 lbs.	37/0.49	40/0.63	32/0.63	28/0.50	137/0.56

Table 7 shows the severity ratio by passenger car size for the four-year total of state trunkline accidents from 1978 through 1981 and study location total accidents in addition to the severity ratios for both CMB single-vehicle and multivehicle accidents.

TABLE 7

Severity Ratios

Passenger Car Size	State Trunkline Accidents (1978-1980)	Study Location Accidents (1978-1981)	CMB (Single-Vehicle) Accidents (1978-1981)	CMB (Multivehicle) Accidents (1978-1981)
Less than 2500 lbs.	0.33	0.41	0.53	0.55
2500 to 3500 lbs.	0.32	0.41	0.52	0.58
Greater than 3500 lbs.	0.32	0.40	0.53	0.56

The severity ratios in Table 5 show very little variation with the exception of the less than 2,500 lb. class which rose to a peak in 1980, then fell in 1981. The data in Table 6 varied a bit more, due to the lower numbers of accidents, but the four-year totals were very close to those of the CMB single-vehicle. Table 7 shows that the severity ratio remained constant regardless of vehicle class for the three accident types.

SUMMARY

There were more CMB accidents per mile per year than left-side guardrail accidents. However, since total accidents increased during the study period, the 1981 percentage of CMB accidents was similar to the 1971 left-side guardrail accident percentage. Similarly, total accidents involving CMB were greater per mile per year than head-on and sideswipe-opposite direction accidents across grass medians. However, the head-on and sideswipe-opposite accidents decreased by 70 percent when CMB was installed in grass medians.

ADT on two roadway segments doubled; however, the typical change was much less, with some segments increasing and some decreasing. The overall change for all study segments between 1971 and 1981 was an increase of three percent.

Median barrier accidents were a relatively constant percentage of total freeway accidents, regardless of the type of barrier in place.

The severity ratio for CMB accidents was greater than that for left-side guardrail accidents where guardrail preceded CMB installation. The differences, however, were not statistically significant. The increase may have reflected only a greater number of unreported accidents in the "after" period. Head-on and sideswipe-opposite direction accidents across a grass median had a higher severity ratio than the "after" period CMB severity ratio. This difference was also not statistically significant.

The number of injury and fatal accidents per mile per year for CMB in the "after" period was approximately double the rate for guardrail in the "before" period. The number of injury and fatal accidents per mile per year for CMB in the "after" period was also higher than the number of head-on and sideswipe opposite direction injury and fatal accidents per mile per year in the "before" period at locations with grass median as the before condition. The number of head-on and sideswipe opposite injury and fatal accidents per mile per year fell 70 percent, however, when CMB was installed.

Multivehicle accidents are a smaller percentage of CMB accidents than of left-side guardrail accidents. Multivehicle injury and fatal accidents are also a smaller percentage of CMB injury and fatal accidents than of left-side guardrail injury and fatal accidents.

Fatal barrier-related accidents decreased by 10 (15 percent) compared to the number of barrier-related accidents expected, computed using the barrier/nonbarrier ratio for 1971-1976 (i.e. the period before widespread CMB use). This decrease was statistically significant at the 95 percent confidence level. Other safety programs which contributed to a decrease in nonbarrier related fatalities complicated this analysis. There were no fatal CMB accidents on the Group I and Group II roadways in the three years after CMB installation. Therefore, it appears that substantial reductions in barrier related fatal accidents occur after CMB installation.

While reductions in all types of accidents are desirable from a traffic engineering perspective, where a choice must be made, fatal accidents will receive primary attention even at the expense of increased property damage and/or injury accidents. The human and economic costs of fatal accidents far outweigh all other types. This must be taken into account when evaluating CMB installations.

Random factors, other than the roadway characteristics analysis, appeared to have the greatest influence on CMB injury and fatal accidents. Average Daily Traffic was the most important roadway characteristic influencing CMB injury and fatal accidents. As ADT increased, injury and fatal CMB accidents tended to increase. The preferred shoulder treatment indicated by this analysis was 7 to 13 feet wide without curb and with a negative shoulder slope. As more data on injury types become available, an analysis of this nature may be useful to identify factors which are associated with increasing severity of injuries.

Very few vehicles crossed the CMB, mounted the CMB, or rolled over as a result of striking CMB on Michigan freeways. The percentages of accidents in which vehicles crossed the barrier or mounted the barrier were both less than found in an earlier study. Although the results were based on a sample of 30 injury and fatal rollover accidents, small cars (under 2500 lbs.) appeared overrepresented in rollovers compared with vehicle registrations.

There was no evidence to suggest that vehicle size has any influence on the severity of CMB accidents.

CONCLUSIONS

A. Barrier-related Accidents

1. Concrete median barriers experienced more reported accidents per mile than median guardrail. However, since total accidents in the study period generally increased, by 1981 the percentage of CMB accidents was about the same as noted for steel beam median accidents in 1971.

2. Total accidents involving CMB were greater than the number of cross-median crashes through grass medians. However, the particularly severe head-on and sideswipe-opposite direction crash decreased by 70 percent when CMB was installed in grass medians.

B. Accident Severity

1. Reported CMB accidents have a higher severity ratio (Injury + Fatal Accidents/Total Accidents) than left-side guardrail accidents. However, the problem of a possibly higher rate of unreported property damage accidents adds some uncertainty to this conclusion.

2. The combined number of CMB injury and fatal accidents per mile per year was about twice that of left side guardrail accidents. (Note: Fatal accidents were relatively few compared to injury accidents, therefore, this number reflects primarily the change in injury accidents.)

3. CMB accidents have a lower severity ratio than head-on and sideswipe-opposite direction accidents associated with grass medians.

4. The combined number of all types of CMB injury and fatal accidents per mile per year was about twice that of head-on and sideswipe-opposite direction injury and fatal accidents per mile per year associated with grass medians. (See note under item B.2.)

C. Secondary Collisions

1. The installation of CMB did not appear to increase the percentage of secondary, multivehicle accidents (i.e., those where a vehicle strikes the barrier and then strikes another vehicle).

D. Fatal Accidents

1. Although the number of CMB injury and fatal accidents per mile per year was greater than in the "before" conditions, both where no barrier (assuming head-on and sideswipe-opposite direction accidents reflect potential barrier accidents) or steel beam guardrail median barrier previously existed, the installation of CMB substantially reduced median-related fatal accidents.

E. Roadway Characteristics

1. The roadway characteristics studied accounted for only 21 percent of the variance in CMB accident severity. This indicates that other factors (speed, driver and vehicle characteristics, etc.) had a greater influence upon CMB accident severity.

2. ADT was the roadway characteristic most strongly associated with injury and fatal CMB accidents.

3. A CMB treatment consisting of a 7 to 13-foot shoulder without curb and with a negative shoulder slope was the safest CMB cross section studied. However, the impact on safety of any cross-section studied was very small.

F. Rollover Performance

1. Six and one-half percent of CMB injury and fatal accidents were rollovers. Less than one percent mounted the barrier, but did not cross and slightly more than one percent crossed the barrier.

2. Small cars (under 2500 lbs.) appeared to be over-represented in the 30 injury and fatal rollover accidents.

G. Influence of Vehicle Weight

1. Vehicle size had little effect on the severity ratio of CMB accidents.

RECOMMENDATIONS

1. Since approximately 80 percent of the variance in CMB injury and fatal accidents was due to factors other than traffic or roadway characteristics, safety considerations probably do not warrant redesigning existing CMB. However, in deciding for or against new CMB, ADT should be the primary safety consideration in favor of CMB. The preferred shoulder treatment for new CMB installations should be 7 to 13-feet wide with no curb and a negative shoulder slope.

2. A larger sample size of rollover accidents needs to be investigated to confirm if small cars are over represented in CMB rollover accidents.

3. The effect of lateral placement of the median barrier on both accident frequency and severity should be investigated. As more data on injury types become available, the severity analysis can be refined.

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11/ "Interim Concrete Median Barrier Study" by Donald Wiertella and Allen Lampela; Unpublished, Michigan Department of Transportation; March, 1976; p. 15.

12/ "Concrete Median Barriers: Are They Effective" by Katie Sowell; Unpublished, Michigan Department of Transportation; December, 1980.

13/ Personal Communication, Dwight A. Bell, Design Supervising Engineer.

14/ Bronstad, Calcote, and Kimball; op. cit.; p 150.

15/ Ibid; p. 14.

16/ Ibid; p. 14.

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APPENDIX

TABLE A

Guardrail/CMB Accident Rates (Percent of Total Accidents)

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Group I: Guardrail in Before Period											
Left-Side, Guardrail Accidents/Mile	2.7(12.3)	3.2(11.3)	2.9(4.5)	2.5(5.0)	2.4(4.9)	2.2(2.4)	1.8(3.0)	1.0(1.5)	0.5(0.8)	0.6(1.1)	0.2(0.4)
Left-Side, CMB Accidents/Mile	--	--	--	--	0.9(1.9)	2.8(3.1)	4.5(7.4)	4.1(6.1)	4.7(7.7)	5.1(9.8)	5.8(11.5)
Group II: Grass Median in Before Period											
Left-Side, CMB Accidents/Mile	-	-	-	-	1.0(6.4)	2.1(13.8)	2.0(11.3)	2.0(13.5)	1.2(8.6)	1.6(13.6)	1.1(10.5)
Head-On & SS-OP Accidents/Mile	0.7(3.8)	0.7(3.8)	0.7(3.4)	0.3(2.1)	0.4(2.5)	0.1(0.7)	0.1(0.6)	0.2(1.4)	0.1(0.7)	0.1(0.8)	0.1(1.0

SEVERITY RATIO
GROUP I
LOG-LIKELIHOOD TEST

	Before Left-Side Guardrail (1)	After CMB (2)	Total
Injury & Fatal Accidents (n)	94	190	284
Accidents (s)	230	349	579

$$\lambda_1 = \frac{n_1}{s_1} = \frac{94}{230} = 0.41 \qquad \lambda_2 = \frac{n_2}{s_2} = \frac{190}{349} = 0.54$$

$$\lambda_0 = \frac{n_1 + n_2}{s_1 + s_2} = \frac{284}{579} = 0.49$$

$$\begin{aligned} T &= 2\,(n_1 \log_e \lambda_1 + n_2 \log_e \lambda_2 - (n_1 + n_2) \log_e \lambda_0) \\ &= 2\,(94 \log_e 0.41 + 190 \log_e 0.54 - (284) \log_e 0.49) \\ &= 2\,(-83.81 - 117.08 + 202.59) \\ &= 2\,(1.70) = 3.40 \end{aligned}$$

$df = 1$ $\qquad$ $0.10 > P > 0.05$

SEVERITY RATIO
GROUP II
LOG-LIKELIHOOD TEST

	Before Head-on, Sideswipe Opposite (1)	After CMB (2)	Total
Injury & Fatal Accidents (n)	17	41	58
Accidents (s)	30	95	125

$$\lambda_1 = \frac{n_1}{s_1} = \frac{17}{30} = 0.57 \qquad \lambda_2 = \frac{n_2}{s_2} = \frac{41}{95} = 0.43$$

$$\lambda_0 = \frac{n_1 + n_2}{s_1 = s_2} = \frac{58}{125} = 0.46$$

$$\begin{aligned} T &= 2\,(n_1 \log_e \lambda_1 + n_2 \log_e \lambda_2 - (n_1 + n_2) \log_e \lambda_0) \\ &= 2\,(17 \log_e 0.57 + 41 \log_e 0.43 - 58 \log_e 0.46) \\ &= 2\,(-9.56 - 34.60 + 45.04) \\ &= 2\,(0.88) = 1.76 \end{aligned}$$

df = 1 $\qquad 0.20 > P > 0.10$

SEVERITY RATIOS
GROUP II
LOG-LIKELIHOOD TEST

	Before Head-on, Sideswipe Opposite (1)	After Head-on, Sideswipe Opposite (2)	Total
Injury & Fatal Accidents (n)	17	4	21
Accidents (s)	30	7	37

$$\lambda_1 = \frac{n_1}{s_1} = \frac{17}{30} = 0.57 \qquad \lambda_2 = \frac{n_2}{s_2} = \frac{4}{7} = 0.57$$

$$\lambda_0 = \frac{n_1 + n_2}{s_1 + s_2} = \frac{21}{37} = 0.57$$

$$\begin{aligned} T &= 2\,(n_1 \log_e \lambda_1 + n_2 \log_e \lambda_2 - (n_1 + n_2) \log_e \lambda_0) \\ &= 2\,(17 \log_e 0.57 + 4 \log_e 0.57 - (21) \log_e 0.57) \\ &= 2\,(-9.56 - 2.25 + 11.80) \\ &= 2\,(0) = 0 \end{aligned}$$

$df = 1$ $\qquad$ $p > 0.20$

1971-1981
MULTI-VEHICLE ACCIDENTS
Paired-t Test

Before (L.S.G.R.)	After (C.M.B.)	d = A-B	d^2
0	0	0	0
11	8	-3	9
1	0	-1	1
7	3	-4	16
3	0	-3	9
1	0	-1	1
0	0	0	0
0	0	0	0
1	0	-1	1
0	0	0	0
0	0	0	0
1	1	0	0
3	5	2	4
1	1	0	0
0	0	0	0
6	5	-1	1
4	4	0	0
0	0	0	0
0	2	2	4
1	0	-1	1
1	1	0	0
1	0	-1	1
1	0	-1	1
2	2	0	0
0	0	0	0
6	1	-5	25
3	1	-2	4
0	0	0	0
0	0	0	0
3	1	-2	4
4	7	3	9
14	41	27	729
11	18	7	49
17	15	-2	4
0	1	1	1
1	4	3	9
0	0	0	0
14	33	19	361
16	16	0	0
0	0	0	0
1	0	-1	1
3	1	-2	4
7	0	-7	49
0	0	0	0
2	2	0	0
1	0	-1	1
0	0	0	0
0	1	1	1
0	0	0	0
		Σ=26	Σ=1300

Ho: B=A

$d = A-B = 0$

$N = 49$

$\Sigma d_2 = 26$

$\Sigma d^2 = 1300$

$\bar{d} = \Sigma d/N = 26/49 = 0.53$

$$s = \sqrt{\frac{\Sigma d^2 - (\Sigma d)^2/N}{N-1}}$$

$$= \sqrt{\frac{1300 - (26)^2/49}{49-1}}$$

$$= 5.18$$

$$t = \frac{\bar{d} - 0}{s/\sqrt{n}} = \frac{0.53-0}{5.18/\sqrt{49}}$$

$$= 0.72$$

$p > 0.10$

1971-1981
MULTI-VEHICLE INJURY AND FATAL ACCIDENTS
Paired-t Test

Before (L.S.G.R.)	After (C.M.B.)	d = A-B	d^2
0	0	0	0
3	3	0	0
1	0	-1	1
2	1	-1	1
0	0	0	0
1	0	-1	1
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
1	1	0	0
3	3	0	0
1	1	0	0
0	0	0	0
5	1	-4	16
2	2	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	1	1	1
1	0	-1	1
0	0	0	0
0	0	0	0
0	0	0	0
5	0	-5	25
3	1	-2	4
0	0	0	0
0	0	0	0
2	1	-1	1
3	4	1	1
8	21	13	169
8	11	3	9
13	10	-3	9
0	0	0	0
1	2	1	1
0	0	0	0
7	18	11	121
12	11	-1	1
0	0	0	0
1	0	-1	1
2	1	-1	1
5	0	-5	25
0	0	0	0
2	1	-1	1
1	0	-1	1
0	0	0	0
0	0	0	0
0	0	0	0
		$\Sigma=1$	$\Sigma=391$

H_o: B = A

$d = A-B = 0$

$N = 49$

$\Sigma d = 1$

$\Sigma d^2 = 391$

$\bar{d} = \Sigma d/N = 1/49 = 0.02$

$$S = \sqrt{\frac{\Sigma d^2 - (\Sigma d)^2/N}{N-1}}$$

$$= \sqrt{\frac{391 - (1)^2/49}{49 - 1}}$$

$$= 2.85$$

$$t = \frac{\bar{d}-0}{s/\sqrt{N}} = \frac{0.02-0}{2.85/\sqrt{49}}$$

$p > 0.10$

FATAL ACCIDENTS
KOLMOGOROV-SMIRNOV TEST

Year	Non-Barrier	Barrier Related Expected (F)	Barrier Related Observed (f)	Cum. F	Cum. f	d
1971	25	9	9	9	9	0
1972	23	8	14	17	23	6
1973	33	12	9	29	32	3
1974	27	9	11	38	43	5
1975	18	6	4	44	47	3
1976	15	5	3	49	50	1
1977	7	2	1	51	51	0
1978	15	5	2	56	53	3
1979	12	4	0	60	53	7
1980	9	3	2	63	55	8
1981	11	4	3	67	58	9

Expected Barrier-Related Fatal Accidents = Non-Barrier Fatal Accidents X 0.35

$$D = \frac{\max.|d|}{n} = \frac{9}{11} = 0.82$$

$p < 0.001$

VEHICLE SIZE
CHI-SQUARE TEST

	Percentage Registrations (E)	Rollovers (O)	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Under 2500 lbs	16.1	30.0	193.2	12.0
2500-3500 lbs	39.0	33.3	32.5	0.8
Greater than 3500 lbs	35.5	23.3	148.8	4.2
Other	9.4	13.4	16.0	1.7
				$X^2 = 18.7$

$df = 3$ $p > 0.01$

5-27-83
PMB:jsm(119A-263)-8
Safety Programs Unit

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STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES                                         11/09/82        PAGE    1

SPSS FOR B6700, VERSION H, RELEASE 7.2, LEVEL 72.001.045.006

DEFAULT SPACE ALLOCATION..     ALLOWS FOR..     50 TRANSFORMATIONS
WORKSPACE      17500 WORDS                     400 RECODE VALUES + LAG VARIABLES
TRANSPACE       2500 WORDS                     600 IF/COMPUTE OPERATIONS

                    NUMBERED       YES
                    RUN NAME       CLYNN/CMB/PREDICTION/SPSS
                    VARIABLE LIST  ALIGN,SHOULDER,GLARE,YEARCMB,CURB,LANE,YEARACC1,
                                   CMBACC1,CMBFAT1,CMBINJ1,ADT1,
                                   YEARACC2,CMBACC2,CMBFAT2,CMBINJ2,ADT2,
                                   YEARACC3,CMBACC3,CMBFAT3,CMBINJ3,ADT3,
                                   YEARACC4,CMBACC4,CMBFAT4,CMBINJ4,ADT4,
                                   YEARACC5,CMBACC5,CMBFAT5,CMBINJ5,ADT5
                    INPUT FORMAT   FIXED(16X,F1.0,F1.0,3X,F1.0,2X,F2.0,F1.0,F1.0,
                                   1X,F2.0,72X,3F4.0,36X,F6.0/3(29X,F2.0,72X,3F4.0,
                                   36X,F6.0/),29X,F2.0,72X,3F4.0,36X,F6.0)


                   ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                   VARIABLE  FORMAT  RECORD    COLUMNS

                   ALIGN     F 1. 0       1     17-  17
                   SHOULDER  F 1. 0       1     18-  18
                   GLARE     F 1. 0       1     22-  22
                   YEARCMB   F 2. 0       1     25-  26
                   CURB      F 1. 0       1     27-  27
                   LANE      F 1. 0       1     28-  28
                   YEARACC1  F 2. 0       1     30-  31
                   CMBACC1   F 4. 0       1    104- 107
                   CMBFAT1   F 4. 0       1    108- 111
                   CMBINJ1   F 4. 0       1    112- 115
                   ADT1      F 6. 0       1    152- 157
                   YEARACC2  F 2. 0       2     30-  31
                   CMBACC2   F 4. 0       2    104- 107
                   CMBFAT2   F 4. 0       2    108- 111
                   CMBINJ2   F 4. 0       2    112- 115
                   ADT2      F 6. 0       2    152- 157
                   YEARACC3  F 2. 0       3     30-  31
                   CMBACC3   F 4. 0       3    104- 107
                   CMBFAT3   F 4. 0       3    108- 111
                   CMBINJ3   F 4. 0       3    112- 115
                   ADT3      F 6. 0       3    152- 157
                   YEARACC4  F 2. 0       4     30-  31
                   CMBACC4   F 4. 0       4    104- 107
                   CMBFAT4   F 4. 0       4    108- 111
```

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                  ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                  VARIABLE  FORMAT  RECORD    COLUMNS

                  CMBINJ4   F 4. 0       4   112- 115
                  ADT4      F 6. 0       4   152- 157
                  YEARACC5  F 2. 0       5    30-  31
                  CMBACC5   F 4. 0       5   104- 107
                  CMBFAT5   F 4. 0       5   108- 111
                  CMBINJ5   F 4. 0       5   112- 115
                  ADT5      F 6. 0       5   152- 157

THE INPUT FORMAT PROVIDES FOR  31 VARIABLES.   31 WILL BE READ
IT PROVIDES FOR  5 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF  157 'COLUMNS' ARE USED ON A RECORD.

                   INPUT MEDIUM   DISK
                   N OF CASES     UNKNOWN
                   MISSING VALUES ALIGN,GLARE TO CMBACC5(O)
                   IF             (ALIGN EQ 2) D1 = 1
                   IF             (SHOULDER EQ 1) D2 = 1
                   IF             (GLARE EQ 3) D4 = 1
                   IF             (CURB EQ 2) D8 = 1
                   IF             (CURB EQ 3) D9 = 1
                   IF             (CURB EQ 5) D10 = 1
                   COMPUTE        SEVERITY=CMBFAT1+CMBINJ1+CMBFAT2+CMBINJ2+
                                  CMBFAT3+CMBINJ3+CMBFAT4+CMBINJ4+CMBFAT5+
                                  CMBINJ5
                   COUNT          N=ADT1,ADT2,ADT3,ADT4,ADT5(1 THRU HIGHEST)
                   COMPUTE        ADTTOTAL=ADT1+ADT2+ADT3+ADT4+ADT5
                   COMPUTE        AVEADT=ADTTOTAL/N
                   ASSIGN MISSING AVEADT(O)
                   COMPUTE        CMBTOT=CMBACC1+CMBACC2+CMBACC3+CMBACC4+CMBACC5
                   COMPUTE        CMBTOTAL=SQRT (CMBTOT+.375)
                   REGRESSION     VARIABLES=D1,D2,D4,D8 TO D10,LANE,AVEADT,SEVERITY/
                                  REGRESSION = SEVERITY WITH D1, D2, D4, D8 TO D10, LANE,
                                  AVEADT(1)/
                   STATISTICS     1

 ***** REGRESSION PROBLEM REQUIRES    279 WORDS WORKSPACE, NOT INCLUDING RESIDUALS *****

                   READ INPUT DATA

AFTER READING     99 CASES FROM SUBFILE NONAME  ,  END OF FILE WAS ENCOUNTERED ON LOGICAL UNIT # 8
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CLYNN/CMB/PREDICTION/SPSS                                                  11/09/82      PAGE    3

FILE    NONAME    (CREATION DATE = 11/09/82)


CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.



                D1          D2          D4          D8          D9          D10         LANE        AVEADT      SEVERITY

D1            1.00000     0.08086    -0.25298     0.00000    -0.08287     0.03780     0.09949     0.10571    -0.02741
D2            0.08086     1.00000    -0.33542     0.34094    -0.66540     0.30562     0.51563     0.61111     0.22865
D4           -0.25298    -0.33542     1.00000    -0.14444     0.11007    -0.04183    -0.16962    -0.13662    -0.13327
D8            0.00000     0.34094    -0.14444     1.00000    -0.24460    -0.19920    -0.04104    -0.14465    -0.19714
D9           -0.08287    -0.66540     0.11007    -0.24460     1.00000    -0.21926    -0.55782    -0.64107    -0.14567
D10           0.03780     0.30562    -0.04183    -0.19920    -0.21926     1.00000     0.70959     0.01681    -0.04079
LANE          0.09949     0.51563    -0.16962    -0.04104    -0.55782     0.70959     1.00000     0.40720     0.08078
AVEADT        0.10571     0.61111    -0.13662    -0.14465    -0.64107     0.01681     0.40720     1.00000     0.36661
SEVERITY     -0.02741     0.22865    -0.13327    -0.19714    -0.14567    -0.04079     0.08078     0.36661     1.00000
```

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CLYNN/CMB/PREDICTION/SPSS                                                          11/09/82        PAGE    4

FILE    NONAME    (CREATION DATE = 11/09/82)

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E    R E G R E S S I O N  * * * * * * * * * * * * *    VARIABLE LIST  1
                                                                                                                    REGRESSION LIST  1
DEPENDENT VARIABLE..     SEVERITY

VARIABLE(S) ENTERED ON STEP NUMBER  1..     AVEADT


MULTIPLE R           0.36661                      ANALYSIS OF VARIANCE     DF      SUM OF SQUARES        MEAN SQUARE            F
R SQUARE             0.13440                      REGRESSION                1.          832.61446          832.61446         15.06139
ADJUSTED R SQUARE    0.12548                      RESIDUAL                 97.         5362.29464           55.28139
STANDARD ERROR       7.43515

----------------- VARIABLES IN THE EQUATION ------------------         ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE            B            BETA      STD ERROR B        F         VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

AVEADT        .9677218E-04    0.36661        0.00002       15.061       D1            -0.06691     -0.07152     0.98882         0.494
(CONSTANT)   -2.897508                                                  D2             0.00737      0.00627     0.62655         0.004
                                                                        D4            -0.08477     -0.09025     0.98133         0.788
                                                                        D8            -0.14719     -0.15654     0.97908         2.412
                                                                        D9             0.15169      0.12513     0.58903         1.527
                                                                        D10           -0.04697     -0.05048     0.99972         0.245
                                                                        LANE          -0.08212     -0.08062     0.83419         0.628


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VARIABLE(S) ENTERED ON STEP NUMBER  2..     D8


MULTIPLE R           0.39448                      ANALYSIS OF VARIANCE     DF      SUM OF SQUARES        MEAN SQUARE            F
R SQUARE             0.15561                      REGRESSION                2.          964.01496          482.00748          8.84604
ADJUSTED R SQUARE    0.13802                      RESIDUAL                 96.         5230.89413           54.48848
STANDARD ERROR       7.38163

----------------- VARIABLES IN THE EQUATION ------------------         ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE            B            BETA      STD ERROR B        F         VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

AVEADT        .9115225E-04    0.34532        0.00003       13:274       D1            -0.06465     -0.06996     0.98859         0.467
D8           -3.018762       -0.14719        1.94394        2.412       D2             0.15471      0.11146     0.43828         1.195
(CONSTANT)   -1.888244                                                  D4            -0.11255     -0.11962     0.95379         1.379
                                                                        D9             0.08397      0.06283     0.47281         0.377
                                                                        D10           -0.07907     -0.08431     0.96017         0.680
                                                                        LANE          -0.07900     -0.07851     0.83386         0.583
```

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FILE    NONAME    (CREATION DATE = 11/09/82)

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *    VARIABLE LIST  1
                                                                                                                  REGRESSION LIST  1
DEPENDENT VARIABLE..     SEVERITY

VARIABLE(S) ENTERED ON STEP NUMBER  3..     D4


MULTIPLE R           0.40951                    ANALYSIS OF VARIANCE    DF      SUM OF SQUARES       MEAN SQUARE           F
R SQUARE             0.16770                    REGRESSION              3.        1038.86745         346.28915       6.38037
ADJUSTED R SQUARE    0.14141                    RESIDUAL               95.        5156.04164          54.27412
STANDARD ERROR       7.36710


----------------- VARIABLES IN THE EQUATION ------------------         ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B            BETA      STD ERROR B         F         VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

AVEADT        .8637237E-04     0.32721        0.00003       11.655         D1            -0.09726     -0.10283      0.93020       1.004
D8           -3.405921        -0.16607        1.96792        2.995         D2             0.11762      0.08198      0.40434       0.636
D4           -2.077578        -0.11255        1.76909        1.379         D9             0.07605      0.05725      0.47159       0.309
(CONSTANT) -0.9226172                                                      D10           -0.08808     -0.09433      0.95465       0.844
                                                                           LANE          -0.09546     -0.09481      0.82095       0.853


* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP NUMBER  4..     D1


MULTIPLE R           0.42012                    ANALYSIS OF VARIANCE    DF      SUM OF SQUARES       MEAN SQUARE           F
R SQUARE             0.17650                    REGRESSION              4.        1093.38279         273.34570       5.03663
ADJUSTED R SQUARE    0.14145                    RESIDUAL               94.        5101.52630          54.27156
STANDARD ERROR       7.36692


----------------- VARIABLES IN THE EQUATION ------------------         ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B            BETA      STD ERROR B         F         VARIABLE       BETA IN      PARTIAL    TOLERANCE          F

AVEADT        .8812257E-04     0.33384        0.00003       12.076         D2             0.10956      0.07665      0.40303       0.550
D8           -3.457540        -0.16858        1.96855        3.085         D9             0.07234      0.05472      0.47123       0.279
D4           -2.521761        -0.13662        1.82372        1.912         D10           -0.08597     -0.09253      0.95417       0.803
D1           -1.548389        -0.09726        1.54492        1.004         LANE          -0.09216     -0.09197      0.82006       0.793
(CONSTANT)  -.8871514E-01
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FILE    NONAME    (CREATION DATE = 11/09/82)

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                 REGRESSION LIST  1
DEPENDENT VARIABLE..     SEVERITY

VARIABLE(S) ENTERED ON STEP NUMBER  5..     D10


MULTIPLE R           0.42843                    ANALYSIS OF VARIANCE    DF       SUM OF SQUARES        MEAN SQUARE            F
R SQUARE             0.18355                    REGRESSION               5.          1137.06517          227.41303        4.18151
ADJUSTED R SQUARE    0.13965                    RESIDUAL                93.          5057.84392           54.38542
STANDARD ERROR       7.37465


----------------- VARIABLES IN THE EQUATION ------------------          ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B              BETA      STD ERROR B        F          VARIABLE         BETA IN     PARTIAL   TOLERANCE          F

AVEADT         .8753144E-04       0.33160        0.00003       11.881        D2              0.29118     0.16448     0.26052       2.558
D8            -3.833339          -0.18690        2.01473        3.620        D9              0.02603     0.01799     0.38997       0.030
D4            -2.633517          -0.14267        1.82989        2.071        LANE           -0.05035    -0.03105     0.31057       0.089
D1            -1.517279          -0.09531        1.54693        0.962
D10           -1.896584          -0.08597        2.11622        0.803
(CONSTANT)    0.3252080


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VARIABLE(S) ENTERED ON STEP NUMBER  6..     D2


MULTIPLE R           0.45347                    ANALYSIS OF VARIANCE    DF       SUM OF SQUARES        MEAN SQUARE            F
R SQUARE             0.20564                    REGRESSION               6.          1273.89671          212.31612        3.96932
ADJUSTED R SQUARE    0.15383                    RESIDUAL                92.          4921.01238           53.48926
STANDARD ERROR       7.31364


----------------- VARIABLES IN THE EQUATION ------------------          ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B              BETA      STD ERROR B        F          VARIABLE         BETA IN     PARTIAL   TOLERANCE          F

AVEADT         .3704847E-04       0.14035        0.00004        0.842        D9              0.04514     0.03153     0.38753       0.091
D8            -6.749243          -0.32908        2.70481        6.226        LANE           -0.02214    -0.01376     0.30703       0.017
D4            -1.715931          -0.09296        1.90327        0.813
D1            -1.302336          -0.08181        1.54001        0.715
D10           -4.379223          -0.19849        2.61036        2.814
D2             4.850595           0.29118        3.03274        2.558
(CONSTANT)     1.840626
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FILE    NONAME    (CREATION DATE = 11/09/82)

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                   REGRESSION LIST  1
DEPENDENT VARIABLE..    SEVERITY

VARIABLE(S) ENTERED ON STEP NUMBER  7..    D9


MULTIPLE R          0.45434                  ANALYSIS OF VARIANCE    DF      SUM OF SQUARES        MEAN SQUARE             F
R SQUARE            0.20643                  REGRESSION               7.         1278.78791          182.68399          3.38158
ADJUSTED R SQUARE   0.14538                  RESIDUAL                91.         4916.12118           54.02331
STANDARD ERROR      7.35006

---------------- VARIABLES IN THE EQUATION -----------------          ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE            B            BETA      STD ERROR B        F           VARIABLE       BETA IN      PARTIAL   TOLERANCE          F

AVEADT      .4466604E-04      0.16921       0.00005       0.872           LANE          -0.00906     -0.00542     0.28447       0.003
D8         -6.410435         -0.31256       2.94226       4.747
D4         -1.651209         -0.08945       1.92481       0.736
D1         -1.289764         -0.08102       1.54824       0.694
D10        -4.125852         -0.18701       2.75519       2.242
D2          4.923380          0.29555       3.05743       2.593
D9         0.8734086          0.04514       2.90269       0.091
(CONSTANT) 0.8608534


F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION

STATISTICS WHICH CANNOT BE COMPUTED ARE PRINTED AS ALL NINES.
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FILE    NONAME    (CREATION DATE = 11/09/82)

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                REGRESSION LIST  1
DEPENDENT VARIABLE..     SEVERITY

                                                             SUMMARY TABLE

VARIABLE                                              MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R           B                 BETA

AVEADT                                                  0.36661    0.13440    0.13440    0.36661      .4466604E-04          0.16921
D8                                                      0.39448    0.15561    0.02121   -0.19714     -6.410435             -0.31256
D4                                                      0.40951    0.16770    0.01208   -0.13327     -1.651209             -0.08945
D1                                                      0.42012    0.17650    0.00880   -0.02741     -1.289764             -0.08102
D10                                                     0.42843    0.18355    0.00705   -0.04079     -4.125852             -0.18701
D2                                                      0.45347    0.20564    0.02209    0.22865      4.923380              0.29555
D9                                                      0.45434    0.20643    0.00079   -0.14567     0.8734086              0.04514
(CONSTANT)                                                                                            0.8608534
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