To obtain a better reference to judge overall barrier performance, a number of tests were performed using a simple vertical faced concrete wall. As it turned out, the ASI values were only slightly worse in case of collisions with severe impact conditions, but there were no rollovers. Under more moderate impact conditions the sloping faced barriers were clearly superior since the vertical wall then continued to impart very high impact accelerations. As it is mainly the lower part of the barrier that is effective under moderate conditions, the combination of a shaped lower part and a vertical or even inwardly inclined upper part seems to gain respectability, since rollovers may be prevented and severity is not greatly increased.

Conclusions

The work on the sensitivity study is not yet completed, because a number of potentially influential parameters have not been investigated. Such parameters can be: slope and friction properties of the road surface adjacent to the barrier, deformation characteristics of the front end of the impacting cars, height of the curb on the lowest part of the barrier etc. Still, it appears that a number of influential factors already have been identified; they can and will be used in the effort to optimize the shape of the barriers. The work with the VEDYAC model can only be considered as preliminary; a model of this type always needs verification. Presently, a conglomerate of Italian road owners, united in SINA, is taking the initiative to carry out an extensive program of full scale tests. They envisage 80 tests, 60 of which will concern concrete barriers. These tests, to be carried out in close cooperation with the designers of VEDYAC, will have to be used for calibration of the VEDYAC model so that an even greater number of tests can be made with the aid of the model. Therefore, the tests will be conducted with great attention to the actual values of important parameters. Calibrating the model however is surely not the only objective of the tests; in the interest of optimal effectiveness and general applicability of results, all interested parties are invited to participate, especially in the planning stage of this project. Results will, of course, be open to the public and available at negligible cost.

MEDIAN BARRIER CRITERIA FOR ALL-PURPOSE DUAL CARRIAGEWAY ROADS - A FEASIBILITY STUDY

by G.R. Watts, Transport and Road Research Laboratory, Crowthorne, Berkshire, England

Abstract

Safety fences on motorway central reserves (median barriers in highway medians) have been accepted as necessary safety features since 1978. However on all-purpose dual carriageway roads where design standards vary it was not until 1981 that such barriers were generally accepted and then only on heavily trafficked new dual carriageways.

The paper describes the initial results from a study designed to develop installation criteria for such barriers. The overall objectives of the study were:

A. to identify road features and traffic flow parameters which contribute to the causation of cross-median accidents and to quantify their effects,

B. to establish on the basis of likely accident cost savings the conditions under which median barrier installations would be cost effective.

The feasibility phase of the study was concerned with reviewing the literature and available accident statistics and developing suitable methodologies for a follow-up study. In this phase accident data for some 700km of dual carriageway were analyzed and geometric data for 64km of such roads collected.

Accident data collected before and after barrier installation give an indication of the decrease in number of casualties from median related accidents. Simple regression analysis shows that some casualty rates are significantly related to flow parameters. Further data will be analyzed by more sophisticated multiple regression techniques in the main study, and before and after studies of all recently protected medians will be made.

Introduction

Median barriers have been installed on motorway medians in the United Kingdom since 1973. On all-purpose dual carriageway roads it was not until 1981 that median barriers were generally accepted, and then they were installed only on busy new dual carriageways. An early study on a 29km section of the M1 motorway showed that when all accidents were considered, there was an estimated nine percent reduction in fatal accidents following installation of the median barrier.

The criteria for installation on dual-carriageway roads used since 1981 was based on this study, but could only be considered as tentative since design standards are quite different on these all-purpose roads.

Motorways are limited access dual carriageway roads with grade separation at all junctions, hard shoulders for emergency stops and with use by pedestrians and pedal cyclists prohibited. All-purpose dual carriageway roads in general have no hard shoulders, a mixture of at-grade and grade-separated junctions, more frequent junctions, service stations immediately adjacent to the road and are not prohibited to any class of road user.

As traffic flows, speeds are more importantly cross-median accidents have increased, there is considerable pressure to produce more refined criteria. At the request of the Engineering Intelligence Division of the Department of Transport in 1984, the Transport and Road Research Laboratory has since December 1984 funded a study by JMP Consultants Ltd to develop appropriate criteria for the installation of barriers on all-purpose dual carriageway roads. The study is due to finish in the spring of 1986, and this paper gives an outline of the study together with some results from its feasibility phase.

Objectives

The overall objectives of this study are:

A. to identify road features and traffic flow parameters which contribute to the causation of cross-median accidents and to quantify their effects,

B. to establish on the basis of the likely accident cost saving the conditions under which median barrier installations would be cost effective.

The study was divided into two parts i.e., a feasibility study and a follow-up study. The aim of the feasibility study was to review the relevant literature and existing accident statistics and, in the light of this, propose one or more methodologies which could provide the best means of meeting the objectives. In the follow-up study it is proposed to carry out the collection and analysis of data on a sufficient scale to achieve significant results using the methods recommended by the feasibility study.

Literature Review

The most relevant British study reported was that carried out on the M1 motorway where a 29km median barrier was installed by TRRL in 1964(1). The accident data for the two years 1962-63 without the barrier and the four years 1965-68 with the barrier erected were compared with those for a contiguous unprotected length of 61km. The accident experience on the trial section before the barrier was installed and on the control section throughout the before and after periods were then used to estimate the number and severity of those which would have been expected on the protected section had the barrier not been erected. Figure 1 illustrates the main findings of actual and expected numbers of accidents. It can be seen that serious cross-median accidents were substantially reduced although there was an increase in the number of serious accidents where the median was not involved. Overall fatal accidents were estimated to have been reduced by nine percent while minor accidents increased in number. Johnson (2) estimated the effect of erecting median barrier on all-purpose dual carriageway using these changes in accident pattern. Employing accident data for nearly 400km of dual-carriageway road he concluded that in general the erection of median barrier would be likely to reduce the number of fatalities by an estimated 15 percent and the numbers of serious and slight casualties would change very little. Obviously there are many differences between motorway and dual-carriageway roads so that the assumption that proportional changes in frequency of the various types of accident following barrier erection on these roads will be checked.

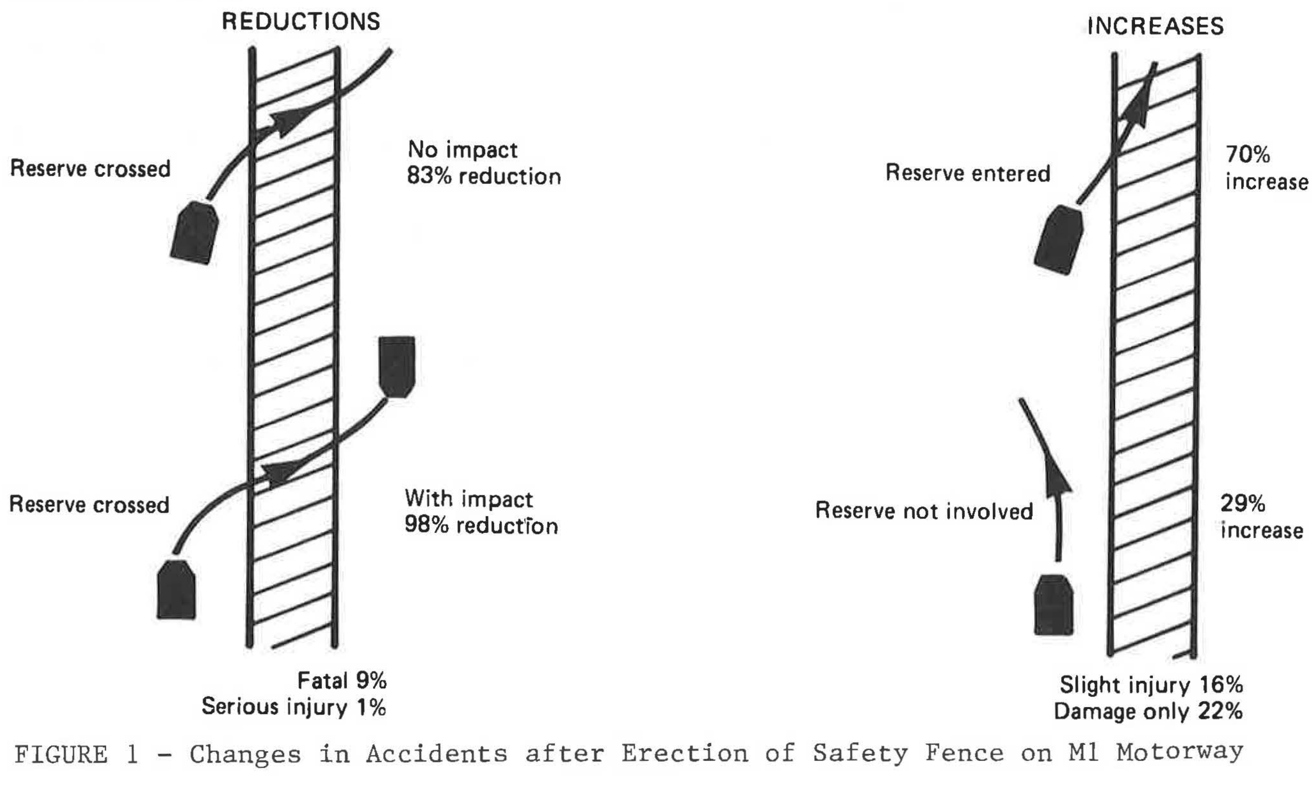

FIGURE 1 - Changes in Accidents after Erection of Safety Fence on M1 Motorway

The available published information have revealed little of relevance to the question of accident causation on dual carriageways. However, there are a number of unpublished studies which have provided valuable background material on costing models and statistical effects.

Design of the Study

Methodologies

As part of the feasibility study various methods of analysis were considered. These were:

- regression modelling.
- pairwise comparisons.
- before and after studies.

Regression Modelling

The following steps are necessary in this approach:

- select a sample of dual carriageway section with barriers.
- select a sample of similar sections without barriers.
- obtain for both samples: accident data (e.g., severity, number of casualties, type of accident), geometric data (e.g., width of median and carriageway gradient), traffic data (e.g., total flow, composition, speed limit).
- analyze the data by fitting an appropriate model. One such model is: accidents/km = f (traffic, geometry, barrier).

If the "barrier" term is significant, then a real effect of the presence of the barrier is indicated. The geometric and traffic terms are included for two reasons. Firstly, to remove the effects of these factors, thus reducing residual variation and increasing the changes of detecting an effect due to barriers. Secondly, to enable the likely accident savings to be plotted against such a variable as total flow and thus be in a suitable form for setting criteria for installation. By examining data from unprotected sections it should be possible to identify factors which appear to contribute to the causation of cross-median accidents and establish relationships.

One difficulty occurs when the samples of protected and unprotected sections are found afterwards to be dissimilar. In particular the two samples may not overlap to a reasonable extent when plotted against one of the important independent variables. It would then be virtually impossible to ascribe a difference in accident level to an effect due to the barriers rather than to the independent variable.

Pairwise Comparison

In this analysis the following procedure is followed:

- select pairs of protected and unprotected sites matched as far as possible on geometric and traffic variables considered to be important.

- obtain full accident data.
- for each pair of sites estimate the difference in accident frequency due to the barrier. A weighted average of these differences would yield the best estimate.

A difficulty would be finding suitable pairs. Adjacent lengths of protected and unprotected sections would probably match the traffic variables although any significant differences in geometry would preclude an unbiased estimate of the effects of barriers. If enough pairs were found, it would be possible to group sites so estimates of accident savings could be made for different ranges of traffic and geometric variables.

Before and After Studies

In this approach the steps are:

- select pairs of sites matched on geometric and traffic variables considered important such that one site in each pair has been recently protected and the other (the "control") has remained unprotected throughout the comparison period.
- for each pair of sites collect full accident data before and after the date of installation.
- determine the difference between the actual and expected accident frequencies.

The major problem is finding enough suitable pairs. If enough sites are found, estimates of accident savings could again be made in terms of the level of an independent variable such as flow. Another difficulty arises in comparing protected and unprotected sections if a length was protected at least partly because it had a high accident frequency. "Regression-to-mean" effects may operate in this case. This means that such sites tend to experience reductions in accident frequency even if no remedial action is carried out, so the benefits of the barriers could be overestimated.

After the completion of the feasibility study it was considered that regression modelling and before and after studies would provide the most appropriate results for setting installation criteria. It was recognized, however, that there may only be limited scope for before and after studies because of the small total length of recently protected dual carriageway. Thirty-two km were identified in the initial phase, and it is estimated that there is unlikely to be more than a total length of about 100km in England. The problems of matching were thought likely to limit the usefulness of the pairwise comparison technique. Nevertheless, a simple form of analysis will be attempted.

Analysis of Accident Data

The accident data is being dissaggregated into four main categories:

Type A - accidents involving a vehicle crossing the median which may or may not collide with a vehicle in the opposite carriageway.

B - accidents involving a vehicle entering but not crossing the median.

C - accidents involving a vehicle rebounding from the median.

D - accidents not involving the median at all.

A median barrier might be expected to reduce the frequencies of type A accidents. Types B and C may increase since situations leading to type A without a barrier may, with a barrier present, produce barrier collisions which produce accidents which are categorized as type B or C. Type D accidents may also increase with a barrier since drivers' avoid actions in an accident situation on the off-side of a carriageway may be inhibited by the fear of colliding with the barrier and so the risk of collision or loss of control within the carriageway may increase. The early study of the barriers erected on the M1 motorway (1) suggested that these changes in the accident pattern do actually occur.

It was considered unlikely that the change in total accidents due to median barriers would be very marked so definite conclusions on benefits would be unlikely. A study of total accidents would probably mask a tendency for a very severe type of accident to be replaced by a less severe one. Therefore, the number of casualties of various severities in the different types of accident is being recorded and this will enable benefits to be more accurately gauged. A knowledge of the "before" mix of the four accident types and the way in which they are likely to be affected by the presence of barriers is considered important in judging the likely benefit of installation.

Types and Sources of Data

From the above considerations of the likely changes in accident pattern it was thought likely that data from substantial lengths of protected and unprotected road would be required if there was to be a reasonable chance of establishing statistically significant criteria.

Three basic types of data are required for the analyses described above:

- geometric data including road geometry, traffic markings, roadside features, gradient, lighting median barrier type and position.
- traffic data including flow of light and heavy vehicles.
- accident data including casualties, severities, type of accident, attendant circumstances.

In the feasibility study only a small amount of geometric data related to 60km of carriageway was collected. In this initial study accident data were collected for approximately 700km of dual carriageway roads in seven counties, of which 121km were protected. In total there were approximately 100 fatal cross-median accidents on these roads in the five year period from 1979 to 1983. Traffic data have been obtained from published data, the counties concerned and the Department of Transport Regional Offices. Accident data for the whole of Great Britain are held on computer files at TRRL. The data are in form of a summary (Stats 19) of the police accident records. The analysis excluded junction accidents and sections of road where special conditions applied (e.g., road works). In the feasibility study, roads in both urban and rural areas with various speed limits were included, but an examination of the number of median involved accidents showed that these accidents were mainly confined to high speed roads. For this reason only dual carriageways with 60 or 70 mph speed limits were considered for inclusion in the follow-up study.

Some Results of the Feasibility Study

Before and After Study

At this stage it is only possible to give a limited set of results from the feasibility study.

The results of a before and after study at five sites are given in Tables 1 and 2. The total length of these sections is 31.6km. Table 1 relates to casualties resulting from accidents involving the median, and Table 2 gives casualty figures for accidents where the median was not involved. No control sections were included, so it is not possible to draw definite conclusions regarding changes in casualty rates.

For casualties resulting from median involved accidents it can be seen from Table 1 that the most marked effect following installation is a reduction in fatal casualties at all sites.

Overall the fatal casualty rate for these accidents decreased 85 percent following installation. In the case of serious casualties the rate decreased at three sites but increased at one, with the overall rate decreasing by 58 percent. For slight casualties the rate decreased at three sites but increased at two sites. In this case the overall rate decreased by only 19 percent.

In Table 2 the changes in casualty rates for accidents not involving the median are listed. For fatal casualties the rate is lower following installation at three sites and at one site the rate is higher; overall there was a 42 percent reduction. For serious casualties the rate decreased at three sites and increased at two sites, and overall the rate was little changed. In the case of slight casualties the rate again decreased at three sites but increased at two sites and the overall rate was increased by 15 percent.

Regression Analysis

Only a simple regression analysis was attempted in the feasibility phase of the study. This determined the relationships between the casualties per km of various severities and the traffic flow, for three accident types. Table 3 lists the correlation coefficients and levels of significance.

The highest correlation of 0.75 was obtained by regressing the number of slight casualties per km from accident type B (accidents where at least one vehicle mounted the median) with traffic flow. Generally, correlations were highest where slight or all casualties were considered. The poorest correlations resulted from regressions involving fatal casualties. The small numbers of fatal accidents per km is one reason for the weak correlations obtained for this class of casualty.

Discussion and Conclusions

The results of the before and after study can be compared with the M1 motorway study. In both cases the biggest reductions following installation of barriers were for the most serious accidents involving the median. In the case of the M1 study (1), although minor accidents increased in number, the erection of the

Site	Section length (km)	Date barrier installed	Number of months data	Casualties				Casualty rate per 10^6 veh-kms			
				Fatal	Serious	Slight	Total	Fatal	Serious	Slight	Total
A	0.7	9/81	b33	0	0	1	1	–	–	0.3700	0.3700
			a27	0	0	3	3	–	–	1.1358	1.1358
B	4.1	11/80	b23	2	5	5	12	0.0330	0.0828	0.0828	0.1986
			a37	0	3	5	8	–	0.0308	0.0513	0.0821
C	8.0	7/82	b43	5	11	16	32	0.0113	0.0249	0.0362	0.0724
			a17	0	2	7	9	–	0.0116	0.0408	0.0524
D	12.3	12/82	b48	6	26	38	70	0.0115	0.0498	0.0726	0.1339
			a12	1	0	7	8	0.0075	–	0.0540	0.0615
E	6.4	7/82	b43	2	9	17	28	0.0065	0.0291	0.0550	0.0906
			a17	0	4	4	8	–	0.0333	0.0333	0.0666
TOTALS	31.6		Before	15	51	77	143	0.0110	0.0375	0.0565	0.1050
			After	1	9	26	36	0.0017	0.0158	0.0460	0.0635

Table 1 - Casualties for Median Involved Accidents on Sections Recently Protected with Barriers from Before and After Study

Site	Section length (km)	Date fence installed	Number of months data	Casualties				Casualty rate per 10^6 veh-kms			
				Fatal	Serious	Slight	Total	Fatal	Serious	Slight	Total
A	0.7	9/81	b23	1	4	4	9	0.3700	1.4797	1.4797	3.3295
			a27	0	2	1	3	-	0.7576	0.3789	1.1364
B	4.1	11/80	b23	0	7	15	22	-	0.1158	0.2484	0.3642
			a37	0	4	28	32	-	0.0411	0.2875	0.3284
C	8.1	7/82	b43	1	11	22	34	0.0023	0.0249	0.0497	0.0770
			a17	0	9	16	25	-	0.0525	0.0934	0.1456
D	12.3	12/82	b48	5	30	71	106	0.0096	0.0575	0.1360	0.2031
			a12	0	5	12	17	-	0.0381	0.0914	0.1293
E	6.4	7/82	b43	2	9	35	46	0.0065	0.0292	0.1133	0.1491
			a17	2	4	8	14	0.0167	0.0333	0.0666	0.1166
TOTALS	31.6		Before	9	61	147	217	0.0065	0.0448	0.1078	0.1592
			After	2	24	65	91	0.0038	0.0458	0.1240	0.1735

Table 2 - Casualties for Accidents not Involving the Median on Recently Fenced Sections from Before and After Study

Type of accident in which casualty occurred	Number of casualties	Class of casualty	Correlation Coefficient (r)	r^2	Level of significance
Where at least 1 vehicle crossed over into the opposite carriageway (type (a))	74	Fatal	0.46	0.20	0.05
	304	Serious	0.63	0.40	0.01
	441	Slight	0.73	0.52	0.01
	819	All	0.67	0.45	0.01
Where at least 1 vehicle mounted the median (type (b))	17	Fatal	0.30	0.09	Not significant
	127	Serious	0.48	0.22	0.05
	384	Slight	0.75	0.55	0.01
	528	All	0.72	0.52	0.01
Where at least 1 vehicle mounted the median and rebounded (type (c))	7	Fatal	0.11	0.01	Not significant
	29	Serious	0.44	0.18	0.1
	64	Slight	0.39	0.13	0.1
	90	All	0.42	0.18	0.1

Table 3 - Correlation Coefficients for Casualties Per km by Flow

median barrier resulted in the almost complete elimination of cross-median accidents in which there was a collision with a vehicle in the opposite carriageway and a very substantial reduction in cross-median accidents without subsequent collision. This resulted in fatal and serious injuries being significantly reduced. In the feasibility study, fatality rates were greatly reduced and other casualty rates were reduced or were similar following installation of median barriers expect for slight casualties resulting from accidents not involving the median where there was a modest increase of 15 percent.

These early results, although of a tentative nature, are encouraging since they suggest that on all-purpose dual carriageway roads the casualties of median-involved accidents are reduced by median barriers while the numbers of casualties from other accidents do not rise substantially.

To obtain statistically significant results, data from greater lengths of recently protected road is required together with that from appropriate lengths of unprotected road which will act as a control. In the main study it is hoped to collect data for most dual carriageway roads in England that have been recently protected. It is estimated that the total length of such road is about 100km.

The results of the regression analysis illustrate the problem of setting appropriate criteria on the basis of cost benefit. By far the most important casualties in accident cost terms are fatalities. These are costed at £150,040 compared with £6,950 for serious casualties and £170 for slight casualties (3). However, because there are few fatal casualties, the regression relationships between numbers of fatal accidents and an important explanatory variable such as flow are relatively weak. For example, the correlation coefficients for fatal casualties with flow vary from 0.11 to 0.46 whereas for slight casualties they vary from 0.39 to 0.75. In an attempt to improve the modelling of accident costs the total length of barrier protected road included in the sample is being increased to 150km in the main study. In addition, geometric data are being collected for all roads and will be used to explain variance and increase the degree of association. It is expected that further improvements can be achieved by using more sophisticated regression modelling methods. The generalized linear modelling technique (GLIM) has proved successful in other accident research studies and will be used in the main study to enable a more precise estimate of the effects of safety fence on accident costs to be made.

By employing these techniques the aim is to establish appropriate criteria for the cost-effective installation of median barriers.

Acknowledgments

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HIGH CONTAINMENT SAFETY BARRIERS: STEEL AND CONCRETE

by Ivor B. Laker, Transport and Road Research Laboratory, Crowthorne, Berkshire, England

Abstract

The development and testing of steel box beam barrier and the construction and testing of a concrete barrier are described; both barriers were impacted with vehicles ranging from a small car to a 38 ton tractor trailer truck. The cars at 112 km/h and the 16 ton trucks at 80 km/h were contained and redirected by both barriers after impacting at an angle of 15 degrees; in addition, a 38 ton tractor trailer truck and a 51 seat bus were redirected by the box beam barrier.

Further work is needed to improve the box beam barrier response to 25 degree impacts. Modification to the concrete barrier may be necessary before impact testing at 25 degrees.

Introduction

Median barriers currently in use in the United Kingdom include the tensioned beam, the open box beam [1] and the rectangular hollow section [2]. Median barriers, usually of the tension beam type, are installed on the medians of British motorways as a matter of course, and on the medians of the busier non-motorway dual carriageway roads. All three types in current use are made of