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Field Study of Rail-Highway Grade-Crossing Crash Sites

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The results of a study undertaken to determine whether an acceptable level of safety has been achieved at the 845 public rail-highway grade crossings in New Mexico are presented. Field studies were conducted at 57 rail-highway grade crossings where one or more accidents had occurred during a 30-month period. With few exceptions, these crossings were found to have adequate design and operational features. Of the sites studied, 35 percent had active traffic-control devices installed after the accident. The project also examined the existing grade-crossing inventory data to determine their accuracy. The study found numerous errors in the inventory file: Principal deficiencies related to highway volumes and advance signs and markings. Evaluation of the data for a limited time period following improvements found an apparently significant reduction in crash experience, which was achieved at a cost of $35 000/accident. The researchers recommend correction of the few deficiencies found in the field study, upgrading of sites that do not meet relevant signing and marking standards, updating of the inventory, and more extensive use of the crossing identification number on accident report forms.

Traffic accidents that occur at the intersection of a rail line and a street or highway are one of the enigmas of highway safety. Available statistics indicate that such accidents are both rare and severe. Their rarity is indicated by the fact that, on an annual basis, at the approximately 220 000 public rail-highway grade crossings in this country there are a total of 11 100 accidents, or an average of 0.05 accident/public crossing/year (1). The severity statistics are also not surprising; the result of several 200-ton locomotives pulling a 5000-ton string of freight cars and striking a 1.5-ton car or pickup is not difficult to predict. What is perhaps surprising is that such a collision does not always result in a fatality. National data indicate that 11 percent of the collisions between trains and highway vehicles result in fatalities and that many of the remainder produce occupant injuries. Although they account for less than 0.1 percent of nationwide traffic accidents, collisions with trains result in approximately 2 percent of the highway fatalities.

In one sense, the grade crossing is just like any other highway intersection where two flows of traffic intersect. However, the generally low train volumes create a situation in which the approaching driver knows that a train may be at the crossing but does not expect one to be there while he or she is actually at the crossing. In an attempt to improve safety at these locations, a variety of static and active traffic control devices can be used to warn approaching motorists and to regulate vehicle traffic when a train is near the crossing. Flashing lights or gates are preferred treatments, but they are expensive, and limited funds for improvement restrict the number of locations that can be treated with these devices.

Through mechanisms with varying degrees of formality, safety improvements at rail-highway grade crossings must compete for funding with a variety of other highway programs that range from spot improvements to new construction. Numerous studies have documented the highly favorable measures of cost-effectiveness for some of these other types of remedial actions. However, once the most hazardous grade crossings have been improved, it is difficult to show a comparable level of cost-effectiveness for the remaining crossings. In fact, it is valid to inquire whether a point of diminishing returns has been reached in grade-crossing safety (2). The objective of this study was to determine whether New Mexico and the three principal railroads that operate within it have, through their previous improvement programs, reached the maximum practical level of safety at rail-highway grade crossings.

Although New Mexico is the fifth largest state in land area, it has only 1960 miles of Class I and Class II rail line, barely 1 percent of the mileage in the entire country. The state has 845 public rail-highway crossings, approximately 0.4 percent of the nationwide total. Accident statistics based on police reports for the 1961-1980 period show that the state averaged 32.5 train-involved accidents/year. Annual fatal and injury accidents averaged 4 and 10, respectively. Although there was a small annual increase in accident experience during this period, the increase is apparently less than the growth of either rail or highway volumes. A 1979 tabulation of grade-crossing accidents and incidents reported to FRA by the railroads shows that New Mexico had 0.24 percent of the nationwide accidents, 0.96 percent of the fatalities, and 0.37 percent of the injuries. Although it is risky to draw strong conclusions from this data base, it appears that the state has fewer but more severe accidents than might be expected in view of its relative share in the number of crossings.

In a typical year, less than 4 percent of New Mexico's public grade crossings have an accident.

As a result, the New Mexico State Highway Department uses a hazard index to help in establishing priorities for countermeasure implementation. The index is a modified version of the New Hampshire method, which includes sight distance, train speed, and accident history parameters in addition to the standard parameters of highway and railroad traffic volumes and a traffic-control-device factor. Like most hazard index methodologies, this procedure calculates a relative value and makes no clear distinction between safe and hazardous. Because the index does not predict accidents, it cannot be used in traditional forms of benefit-cost analysis (3). It may be useful for setting priorities among potential grade-crossing improvements, but it is of minimal value in allocating funds among competing safety programs.

In recent years, the Highway Department, using this index and input from a diagnostic team, undertook a vigorous program of grade-crossing improvements. At approximately 11 percent of the crossings, active devices (costing, on the average, $60 000) were installed, and, at many others, signs and markings were installed or upgraded. Despite these improvements, there was an average of 32 accidents/year for the 1978-1980 period, which was almost identical to the experience in the preceding 17 years. At this point, responsible highway officials began to question the results of their efforts and to seek a more thorough analysis of the consequences of their program.

STUDY PROCEDURES

To achieve the objectives of this project, a research plan involving computer analysis of National Railroad Grade Crossing Inventory data and a field study of accident sites was developed and implemented. Combined input from both data sources provided a means of evaluating the accuracy of the national inventory.

Data for the initial inventory were collected by the railroads and the New Mexico State Highway Department in 1974. The inventory contains 78 data items for each public grade crossing in the state. With the notable exception of sight distance, the inventory contains information on most of the relevant physical and operational features at rail-highway grade crossings. The seven-digit crossing number provides a means of relating the inventory information to other data bases, such as the FRA accident file. At the time of the study, the established mechanism for updating inventory information had been used extensively by the railroads but sparingly by the Highway Department.

Several basic crossing characteristics are summarized in Table 1. Traffic volumes at the crossings are generally low; only 19 percent have average daily traffic (ADT) in excess of 1000 vehicles. The comparatively minor nature of many of the roads is supported by their functional classification (57 percent are classified as other local roads) and the fact that only half the roadways were paved. The busiest rail line has 46 trains/day. The average crossing has 1.46 tracks.

The inventory provides extensive information on the type of warning device at the crossing. FRA classifies these according to a hierarchy from no devices (1) to gates (8), characterizing the crossing protection level by the highest level of warning device. Table 2 summarizes the highest warning level for nine categories of traffic volume. Crossbucks are the predominant form of traffic-control device, accounting for the highest level of protection at 68 percent of the crossings. Active devices are in use at 29 percent of the crossings. For those crossings with estimated ADT of 1250 or more, 73 percent had active devices. In general, higher levels of protection are provided at crossings with higher traffic volumes. A separate analysis showed a rank order correlation of +0.57 between traffic volume and protection level, which is highly significant for the sample size. The correlation between number of trains per day and highest level of protection is +0.37, which is also statistically significant.

In addition to signs and active devices at the crossings, the inventory contains information on the use of pavement markings and advance-warning signs. The railroad advance-warning sign (W10-1) was reported at only 168 (20 percent) of the crossings. Because the sign is placed several hundred feet in advance of the crossing, its presence may not have been detected by technicians conducting an inventory from the tracks. The inventory data indicate that 61 (7 percent) of the crossings had standard pavement markings prescribed for railroad crossings. More specifically, 57 sites had the RR symbol on the pavement, and 45 provided a stopline.

The inventory data were analyzed by using correlation techniques to determine relations among the several variables. This analysis showed that, where

Table 1. Characteristics of New Mexico grade crossings.

Characteristic	Low	High	Avg	Median
ADT (no. of vehicles)	5	27 000	1040	100
Trucks (%)	0	93	8.2	5
Daily trains				
Day	0	23	5	3
Night	0	23	4	2
Train speed (mph)	0	90	42	49
Number of tracks				
Main	0	3	0.90	1
Other	0	7	0.56	0

Table 2. Highest warning level used at crossings by volume of vehicle traffic.

	No. of Crossings Using Device						
Traffic Volume	None	STOP	X-Buck	Wigwag[a]	Light	Gate	Total
<100	11	2	394	5	7	12	431
100-200	0	1	62	0	9	10	82
200-400	2	1	41	2	14	15	75
400-625	4	0	20	1	11	9	45
625-1250	1	1	20	0	26	18	66
1250-2500	0	0	15	2	21	19	57
2500-5000	0	0	9	0	12	19	40
5000-10 000	0	0	8	0	8	14	30
>10 000	0	0	7	0	3	9	19
Total	18	5	576	10	111	125	845

[a]Includes bells and highway traffic signals.

Table 3. Average rail-highway crossing characteristics.

Characteristic	Accident Crossings	Nonaccident Crossings
Highway ADT	2200[a]	960
Trucks (%)	7.9	8.2
Number of daytime trains	8.0[a]	4.7
Number of nighttime trains	7.0[a]	3.9
Total number of trains	15.0[a]	8.6
Train speed (max mph)	50.2[a]	41.9
Number of highway lanes	1.98[a]	1.75
Number of main tracks	1.12[a]	0.88
Number of other tracks	0.37	0.58[b]
Total number of tracks	1.49	1.46
Warning device class[c]	5.98[a]	4.86
Number of crossbucks	0.57	0.92[b]
Number of STOP signs	0.12	0.03
Number of other signs	0.05	0.04
Number of bells	0.61[a]	0.30
Number of flashers	1.45[a]	0.62
Number of traffic signals	0.11	0.01
Number of gates (red/white)	0.54[a]	0.20

[a]Significantly higher at the accident sites at $\alpha = 0.05$.
[b]Significantly higher at the non-accident sites at $\alpha = 0.05$.
[c]From no warning (1) to gates (8).

traffic volumes are higher (principally in urban areas), there tend to be fewer main tracks, more other tracks, and lower train speeds. Crossings with higher train volumes tend to have more main tracks and higher speeds. Sites with higher train speeds generally have more main tracks and a higher level of protection, whereas the number of highway lanes and other tracks is typically lower. In addition, the protection level was generally higher for crossings with more highway lanes, main tracks, and other tracks. None of these correlations is particularly surprising. They basically show that more important crossings--as reflected by higher volumes (trains and vehicles), speeds, and number of tracks--are better protected.

FIELD STUDIES

Although the inventory contains a substantial amount of information, it is not comprehensive with respect to some highway parameters, such as alignment and sight distance, which may be significant in causing accidents. In addition, because the highway data in the inventory had not been updated on a periodic basis, the accuracy of some inventory information was questionable. In an attempt to address these issues, field studies were made at 57 grade crossings at which there had been 67 train accidents during a 30-month period ending in December 1979. During the review and analysis of data on grade-crossing accidents, discrepancies were noted in the number and location of accidents contained in the Highway Department and FRA record systems.

The field measurements and observations were designed to verify and supplement the inventory data. Observations were used to check inventory data on such things as traffic-control devices, number of tracks, advance-warning devices, and the presence of nearby intersections. Measurements were made of roadway alignment, crossing profile, and control-device placement as well as approach and AASHTO Type III sight distance. The techniques for making these measurements are described in the research report (4). Supplementary information on the operational characteristics of the crossings was provided by the Highway Department and the railroads.

DATA ANALYSIS

The seven-digit crossing number, an integral part of the inventory system, should permit comparison between crossings that have experienced train-vehicle collisions and those where there were no such accidents during the study period. The usual failure of the investigating officer to include this number on the accident report complicates the process of determining the actual crossing number of the accident sites. With the assistance of the Highway Department files and through the field studies, it was possible to make a reliable determination of the crossing number of the accident sites. Then it was a rather straightforward process to compare the inventory characteristics of crossings where accidents had occurred and those where accidents had not occurred.

Table 3 compares the 1980 inventory information for the two categories of crossings. The crossings that experienced accidents are clearly more active: They have twice the train and highway volume of public crossings that did not have accidents during the study period. They also have significantly more highway lanes and main tracks and significantly fewer other tracks. Maximum typical train speeds are also significantly higher. The protection level is higher at the crossings where there were accidents, as evidenced by the significantly larger number of bells, flashers, and red-white gates.

By using the protection factor coefficients used in the New Hampshire hazard index (i.e., 1.0 for signs, 0.6 for flashing lights, and 0.1 for gates), the average protection coefficients were found to be 0.62 for the crossings with accidents and 0.82 for the crossings without accidents. The values are significantly different, verifying what is implied in Table 3--that is, that better protection is provided at the crossings where accidents occurred. The New Hampshire index for all public crossings averaged 2640. For crossings with accidents, the index averaged 9030, which is significantly higher than the index of 2180 for the crossings without accidents. This finding indicates that, as a group, the crossings with accidents, despite their higher protection levels, are more hazardous than the much larger set of crossings where accidents did not occur during the study period.

Another item of concern with respect to the inventory is the accuracy of the data it contains. The basic inventory data were collected in 1974. As grade-crossing improvements are made, the railroad submits an updated inventory form to the Highway Department, which in turn modifies the highway data (if necessary) and forwards the information to FRA. Of the crossings studied in this research, 25 (45 percent) were updated since the original data collection, mostly in response to improvement in traffic-control devices.

The accuracy of the physical information at the site was established by comparing the inventory with the conditions actually observed in the field. Of the crossings studied in this research, 42 (74 percent) exhibited physical conditions in the field that differed from those listed in the inventory. By far the most prominent error in the inventory is its failure to document the actual presence of the railroad advance-warning sign (W10-1). At nearly half the accident sites, the inventory indicated that this sign was not present when in fact it was placed on one or both approaches. Because the original inventory data were collected by a team moving along the track rather than on the highway, it is reasonable to expect that this sign could be easily overlooked. The next most common errors involved the failure to note the presence of pavement markings, specifically the RR symbol and stoplines. It is quite possible that the markings, which have a relatively short lifetime, were not in place when the inventory was initially conducted.

Table 4. Alignment characteristics at accident sites.

Characteristic	Mean	Min	Max
Curvature			
150 ft[a, b]	0.48	-15.51	21.27
50 ft[a, b]	-0.26	-15.42	24.11
Average	0.11	-13.90	18.63
Modified[c]	-0.38	-10.00	10.00
Absolute[d]	1.40	0	18.63
Gradient			
150 ft[a]	0.34	-5.00	7.60
50 ft[a]	1.47	-2.80	7.20
Average	0.91	-2.40	5.75
Approach profile[e]	3.17	-1.94	10.78
Departure profile[e]	-3.06	-9.80	2.84
Superelevation			
150 ft[a]	1.71	-3.00	7.20
50 ft[a]	1.96	-3.30	8.80

[a] Distance in advance of the rail tracks.
[b] Curves to the left were assigned positive algebraic signs.
[c] Truncated to values between -10° and +10°.
[d] Absolute value of the average curvature.
[e] Established from level readings at the rail and 50 ft on either side. "Approach" is the direction of the vehicle involved in the accident.

Table 5. General characteristics at accident sites.

Characteristic	Sites (%)
Land use	
Commercial	46
Farming	45
Residential	9
Level of development	
Heavy	28
Moderate	40
Light	15
Undeveloped	17
Type of area	
Rural	40
Suburban	3
Town	57
General approach alignment	
Horizontal	
Tangent	70
Curve left	14
Curve right	16
Vertical	
Level	72
Upgrade	19
Downgrade	9
Protective devices that need physical maintenance	30
Sites with official, nonrailroad traffic-control devices	43

According to the inventory guidelines, a nearby intersecting highway is one within 75 ft of the crossing. This characteristic, which is not likely to change much over time, is improperly coded for 8 (14 percent) of the sites. These and other major error categories and the number of crossing sites (of the 57 sites studied) at which errors were noted are given below:

Category	No. of Sites Where Error Was Noted
RR advance-warning sign	27
RR symbol (pavement marking)	21
Stopline (pavement marking)	16
Nearby intersecting highway	8
Red and white gates	7
Bells	5
Passing zone markings	4
Number of train tracks	3
Number of highway lanes	3
Miscellaneous	10

Miscellaneous includes the presence of flashing lights, crossbucks, STOP signs, other (exempt) signs, and crossing surface characteristics.

Table 6. Placement of official railroad traffic control devices.

Device	No. of Sites	Distance from Rail (ft) Avg	Min	Max	MUTCD
Gates	29	12.8	9	17	10 min
Flashers	41	15.6	10	40	10 min
Crossbuck[a]	58	16.7	10	51	6-50
Stopline	25	24.3	14	91	15
RR symbol	28	207	48	568	Variable
Begin no passing zone	18	278	84	769	Variable
RR advance warning sign	37	296	28	769	100-750

[a] Includes crossbucks on active devices.

The Highway Department was able to provide traffic volume data for eight study sites on their roadway system, but reliable traffic volumes for other roads were not available. On the state highway system, current volumes ranged from 66 to 650 percent of the values included in the inventory. The current average highway volume is 121 percent of the average volume values from the inventory. Only two of the state highway sites for which new volume data were available had been updated, both in response to the installation of gates.

The three railroads that owned the crossings at the study sites provided information on their current operating conditions. In general, the railroads have been conscientious in submitting updated information for crossings where traffic-control devices had been changed. However, the updated information they had submitted through the established channels in early 1981 was not reflected in the inventory file used for this research.

The railroads reported changes in the number of daily trains at 26 crossings. These volume changes were equally divided between increases and decreases. Actual current daily volumes ranged from 47 to 180 percent of the inventory values, and there would be a corresponding effect on the value of the hazard index calculated for these crossings. In one case, daily train movements increased from 36 to 57; in two others, the increase was from 46 to 64. Other changes in this parameter were considerably smaller. It must be noted that some deviation in daily train volume is expected, and it would be unreasonable to expect any inventory to specify precisely a value in which there is such inherent variation. Train speed, which is an important input to sight distance calculations, was incorrect in the inventory data for 18 crossings. The current speeds reported by the railroads were generally lower than those shown in the inventory.

ANALYSIS OF FIELD SITE DATA

Measurements of the roadway alignment in the direction traveled by the highway vehicle involved in the accident are summarized in Table 4. The roads were basically tangent; 80 percent had a curvature of 0°. Several of the sites with high curvature (>10°) were actually near intersections where the vehicle made a turn just before colliding with a train. Although the presence of nearby highway intersections may affect the safety of a crossing, it is quite possible that roadway curvature is not a proper measure to use to indicate this influence.

As expected, the approach gradient on the highway was generally positive (at 72 percent of the sites). The average value of +1.47 percent, measured at a point 50 ft in advance of the tracks, is significantly greater than zero. A level and rod were used to establish the profile (average gradient) over the 50-ft sections immediately before and beyond the tracks. These measurements probably give the truest reflection of the sudden elevation change experienced by a vehicle traversing the crossing. The average values of these grades (3.1 percent) were virtually identical for the approach and departure sides of the track, although their algebraic signs, of course, differed.

Evaluation was made of the adequacy of sight distance for motorists approaching the track as well as for those who are legally stopped at the crossing. It was found that 19 crossings (33 percent) had sight distance deficiencies in one or more of the quadrants. This statistic may overstate the seriousness of the problem, however, because 14 of these crossings are controlled by active devices (flashing lights or gates) that can be seen by approaching motorists. The presence of these devices significantly reduces the importance of sight distance along the tracks.

Some general characteristics of the sites are summarized in Table 5. Land use was found to be predominantly commercial and farming and nearly equally divided between these two categories. Although nearly 60 percent of the sites were in urban areas, less than 30 percent had heavily developed land adjacent to the crossing. The general alignment characteristics of the road over a 0.25-mile approach in the direction traveled by the vehicle involved in the crash are generally similar to those measured at 50 and 150 ft before the crossing. Specifically, 70 percent were tangent and more than 70 percent were level. Upgrades were found twice as frequently on the approaches as downgrades.

Official railroad crossing traffic control devices were positioned by measuring distances from the nearest rail. The Manual on Uniform Traffic Control Devices (MUTCD) permits some leeway in the longitudinal placement of flashers, crossbucks, and other devices. Actual placement is determined on the basis of factors such as alignment and vehicle speed. Table 6 summarizes information on the actual longitudinal placement of official railroad traffic control devices at the study sites and also identifies, for comparison purposes, the standards from the MUTCD. Almost all of the devices appear to be placed in accord with the standards.

CROSSING IMPROVEMENTS

Beginning in 1976, the Highway Department initiated an aggressive program of rail-highway grade-crossing safety improvements. Since that time, numerous crossings have been treated with static devices and 98 were improved with flashing lights or gates. Among the sites with major improvements, accidents occurred at 23 during the 30-month study period. At 3 of these crossings, accidents occurred after the installation of gates; the remaining 20 were improved an average of 14 months after the accident. In several cases, it appears that the improvement was planned but not implemented before the date of the crossing accident. The apparent role of accident experience in the selection of crossings for improvements would seriously bias a traditional before-and-after study of countermeasure effectiveness.

Because most of these improvements in traffic control devices are reflected in the inventory, the current inventory data do not properly indicate the crossing conditions at the time of the accident. There was no indication that other physical factors, such as alignment or sight distance, were changed between the time of the accident and the field study.

At the completion of this study in 1981, it was difficult to assess the effect of these improvements. Between 1961 and 1976, statewide annual accidents averaged 33. Linear regression analysis of the data for this period showed an average increase of 0.76 accident/year. During the late 1970s, while improvements were being implemented, accidents averaged 31/year. The 95 percent prediction limits for 1980 accident experience were 41.6 ± 13.6, and the actual number of accidents (31) is within this range. The similar limits for 1981 accident experience are 42.3 ± 13.9, whereas the actual accident experience was 22, the lowest value in more than 20 years. The most recent data suggest a significant downturn in train accidents despite increases in highway and train volumes, and it is logical to attribute the change to the crossing improvement program.

If the costs of all grade-crossing improvements in New Mexico between 1976 and 1980 are amortized over a 20-year lifetime, the annual improvement cost is approximately $700 000. Assuming the apparent reduction of 20 accidents/year, as suggested by the predicted and observed values for 1981, the cost of eliminating one accident through grade-crossing improvements is $35 000. Although data for one or two more years are needed to verify these findings, it appears that grade-crossing improvements may be more cost effective than previously thought.

CONCLUSIONS

Although traffic accidents involving trains account for only 0.06 percent of highway accidents in New Mexico, rail-highway grade crossings have received considerable attention in recent highway safety improvement programs. A computerized study of crossings where accidents occurred showed that they have substantially higher volumes of train and vehicle traffic than a set of nonaccident crossings and, despite their higher protection level, their hazard indices are also higher. Field studies of accident sites found no consistent pattern of highway deficiencies that might contribute to accidents, although several sites exhibited adverse alignment or poor sight distance. The location of warning and traffic-control devices at these sites was in compliance with existing standards. Inventory data for the crossings were often in error. The principal deficiency was errors in the highway information. For a variety of reasons, including the number of parameters included in the inventory data base, the timeliness of the data, the failure to update in response to new signs and markings, and the poor quality of volume data on local roads, it can be stated with reasonable certainty that the inventory has at least one error or omission for each public crossing. Probably the most important omission is the failure in many cases to include the street name at the crossing. Along one major railroad in the state, less than half the crossings show a street name or highway number for the intersecting roadway. This, of course, makes it difficult to match inventory and accident data. Significant errors in highway and train volumes were also found in the inventory. An FRA report (5) shows that problems with the inventory are not unique to New Mexico.

Data for the year following completion of the extensive crossing improvement program show a significant reduction in accident experience. This preliminary information suggests that the reduction is being achieved at a cost of $35 000/accident, a value that may be appropriate for those accidents that have a severity index of 0.5.

It is difficult to conclude with certainty whether or not an acceptable level of safety at grade crossings has been achieved in New Mexico. Accident experience has decreased in the past few years at these locations. However, the Transportation Systems Center (TSC) accident prediction models (6), which rely in part on inventory data, suggest that there is still room for improvement. Although 39 of the sites studied in this research were in the top 100 according to the TSC models, 61 other crossings with an annual expected accident experience of 0.07-0.25 have not had a recent accident. According to a more traditional index, these 100 crossings are more hazardous than the sites studied in this project. Furthermore, because at 37 of the top 100 sites crossbucks are the highest level of protection, it would appear that continued attention to the problems of grade-crossing safety in New Mexico may be warranted.

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