Use of Traffic-Conflicts Technique to Assess Hazards of Transporting Oversize Loads

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The traffic-conflicts technique was used to assess the hazards associated with transporting oversize loads over highways. The approach was based on the assumption that a driver applies brakes in response to a perceived danger when following, passing, or meeting other vehicles. Field tests were conducted to determine whether there are any differences in the hazards involved in moving 3.7-m (12-ft) wide housing units as compared with those of moving 4.3-m (14-ft) wide units. An analysis of the conflicts indicated that there were no major differences; however, the sample size was too small for the results to be accepted with a high degree of confidence. Although the conflicts data indicated that the large sample sizes needed to establish statistically reliable results may not be practical, the technique was useful in determining the types and relative frequencies of hazards associated with the movement of wide loads over a variety of highway systems. As a measure for assessing the hazards of moving wide loads, the conflicts technique provided more detailed information in a short period of time than could have been obtained from a conventional accident analysis.

This assessment of the hazards involved in moving oversize loads over highways was initiated when the Virginia legislature requested an evaluation of the potential effects of moving 4.3-m (14-ft) wide housing units over the state's roads. In Virginia, and in most states, the movement of oversize mobile and modular housing units is regulated to protect the motoring public from unnecessary hazards and inconveniences. However, there has been little study of the effects of oversize loads on other traffic. The only comprehensive study of the movement of 3.7- and 4.3-m (12- and 14-ft) wide housing units was conducted in 1973 by the Midwest Research Institute. The results of the study (1) suggested that "the question is not a simple one and, unfortunately, the data obtained in this study do not clearly show that states should or should not allow [4.3 m] 14-foot wide loads."

One of the primary concerns about the movement of wide loads is their effect on the safety of the traveling public. Although accident data seem to indicate that 3.7-m-wide loads are seldom involved in reportable accidents, it has been suggested that wide loads create causal factors that lead to accidents in which they are not directly involved (1, 2). Because of the rarity of reported accidents and the difficulty of obtaining accurate exposure (vehicle kilometers of travel) and accident information, the question of safety in moving wide loads is unresolved.

Although the use of accident data provided a poor measure for the evaluation of the safety of moving 3.7-m-wide loads, no data were available about 4.3-m-wide units because these units were prohibited in Virginia. Accident reports from states that allow travel of the 4.3-m-wide units provided little information. Because the Virginia legislature's resolution required that the evaluation be conducted within a five-month period, it was necessary to use a measure of safety other than accident reports.

The purpose of this paper is to present the methodology and results of field tests conducted to identify the type and frequency of hazards that occur during the transportation of oversize housing units. The specific objectives of the study were to examine the hazards that affect the traveling public, the wide load itself, and the highway system and to determine whether significant differences exist between hazards presented by 3.7-m-wide units and those presented by 4.3-m-wide units.

ALTERNATIVE METHODS OF MEASURING HIGHWAY SAFETY

Conventional methods of measuring highway safety rely on the use of accident records. Although accident data are widely accepted measures, there are a number of disadvantages in using them to measure safety. These disadvantages include (a) incomplete or inaccurate reports, (b) the high percentage of accidents not reported, (c) year-to-year fluctuations in numbers of accidents, (d) the failure of the records to identify specific problems and causal factors, and (e) usually of greatest importance, the long time interval required to accumulate a sufficient amount of data after any change is made in the environment-vehicle-driver system (3). Because of these deficiencies, the need for additional measures of safety that can be used to supplement accident data has long been recognized.

In recent years, several non-accident-based methods of measuring highway safety have been developed. Because the legislature required that the hazards of moving oversize loads be evaluated within a short period of time, the number of possible safety indicators that could be used was limited. Based on a review of the literature, the following techniques were considered: (a) acceleration noise, (b) erratic maneuvers, (c) near-miss events, and (d) traffic conflicts. Although all of these measures have been used in other studies, they have not been used to assess the type and frequency of hazards that occur during the movement of a load along a highway.

Acceleration noise has been used as a traffic parameter that describes the hazard of driving on a particular highway (4). Because of the instrumentation problems imposed by using a variety of mobile and modular units, the method was not used for the present study; another disadvantage of the method is that the technique is not sensitive to the hazards posed by a moving load to other traffic and the highway system.

To examine the applicability of either erratic maneuvers, near-miss events, or traffic conflicts, several test runs that used 3.7-m-wide loads were conducted. The results of the pilot study are summarized below.

Broadly defined, an erratic maneuver is an unusual single-vehicle movement. Current application of the technique has been limited to evaluating the movements of vehicles at exit gore areas (5). Because very few unusual single-vehicle maneuvers were encountered during the test runs, the use of erratic maneuvers as an evaluative tool was eliminated from consideration.

Because the primary hazards observed during the test runs were vehicle-load interactions, the possibility of modifying either the near-miss criterion or the traffic-conflicts technique was explored.

A near-miss event is defined as a serious traffic conflict in which the measured minimum time to collision of two vehicles is equal to or less than 1 s (6). Although near-miss events have thus far been used only for the assessment of the hazards of vehicle interactions at intersections, the concept of developing a minimum time to collision for vehicles in motion along a highway appeared to be possible. However, in nearly 644 km (400 miles) of travel during the test runs, no critical near-miss situations were observed. Consequently, the technique, as well as the possibility of developing a minimum time to collision for moving loads, was eliminated from consideration.

TRAFFIC-CONFLICTS TECHNIQUE

The traffic-conflicts technique was developed at the General Motors Research Laboratories as a method of observing and recording potential accident maneuvers at intersections. A traffic conflict is an evasive maneuver by a driver who either brakes, as indicated by a brake-light signal; changes lanes to avoid a collision; or commits a violation of the uniform traffic code. Specific conflict criteria and study procedures for intersections are described in the literature (7).

The theoretical basis for using conflicts data as a measure of safety is that conflicts describe hazards that can lead to accidents. Several workers have discovered significant relationships between conflicts and accidents at intersections (8-10). Also, conflicts have been found to be heavily dependent on traffic volume (11).

Unlike accident data, which may take several years to collect, conflicts data can be collected in a short time. However, a major disadvantage is that the definition of a conflict is subjective and conflict counts taken simultaneously by different observers at the same location can vary. Also, a recent evaluation of the technique showed that the large sample sizes required to establish reliability and utility of the analysis may not be practical (12).

In addition to its use at intersections, the traffic-conflicts technique has been applied with some modifications to the diagnosis of problems and the evaluation of the effects of various treatments at gore areas on freeways, long upgrades in mountainous terrain, and driveways (10, 12).

APPLICATION TO MOVEMENTS OF OVERSIZE LOADS

Although the traffic-conflicts technique had not previously been applied to the examination of the hazards associated with a moving oversize load, the results of the pilot study indicated that it might be applied successfully. Thus, on the assumption that a driver applies brakes in response to a perceived danger when following, passing, or meeting a wide load, the technique was used to evaluate the hazards in moving oversize loads.

Definition

One of the first requirements of the study was the development of a suitable definition of a conflict that could be used for all moving loads. Based on the preliminary tests, a traffic conflict was defined as an evasive maneuver, as evidenced by a brake-light indication, taken by a driver operating a vehicle in the vicinity of a wide load. The definition also was taken to include evasive maneuvers by a driver pulling a wide load in the vicinity of other traffic or narrow roadside obstructions (fixed objects). It did not include braking because of traffic-control devices (such as traffic signals and stop signs) or conflicts between wide loads and their escort vehicles (because escorts were considered to be integral components of the load). In addition, violations of the traffic code, e.g., driving to the left of a double solid centerline, were not taken as constituting conflicts. No attempt was made to define the severity of conflicts because the objective of the study was to identify all hazards.

Method

To provide a basis for evaluation, conflicts data were taken for both 3.7-m-wide units—the standard product—and 4.3-m-wide units—the product being evaluated. The housing units evaluated consisted of mobile, double-wide, and modular sections transported under permit in accordance with Virginia regulations for oversize loads. Housing manufacturers throughout the state provided the units, drivers, and escorts. Most of the units were driven from the plant to their final destination; however, occasionally, one was specially routed to include a variety of roadway geometric and traffic conditions. The study routes consisted of sections of Interstate, multilane and two-lane primary, and secondary routes. The sections were selected from routes throughout the state and represented a broad range of traffic, geometric, land-use, and environmental conditions. Both sizes of units were transported over each study route.

Data Collection and Reduction

Traffic-conflicts data were collected by a four-person crew that used two 16-mm cameras. A driver and a photographer rode in each of two unmarked research vehicles, one driven approximately 0.4 km (0.25 mile) ahead of the wide load and the other the same distance behind the load. As a vehicle approached or passed the load, the cameras were activated and the entire interaction was filmed. The purposes of filming from two directions were to maximize the number of observations and to provide as full as possible coverage of the vehicle-load interactions. Other data recorded on film included vehicle and load lateral placements and load encroachments at intersections and roadside obstacles. In addition to the film data, manual counts were made of the vehicles that formed queues behind the loads or passed or approached from the opposing direction of travel. Other data collected manually included load and roadway dimensions, load speeds, queue lengths and impedance times, vehicle passing times, and violations of permit regulations. The data were collected from August 16 to October 7, 1967, between 9:00 a.m. and 4:00 p.m. on Mondays through Thursdays.

During the planning of the research, there was concern that the presence of the vehicles and cameras used to collect the data would influence the behavior of the wide-load operator, the escort-vehicle operators, and the traveling public. Therefore, several practice trips were made with the research vehicles at various distances from the wide load and citizens' band radio transmissions were monitored to determine the relative interest of the public in the research vehicles and their operations. Only a few persons with radios noticed the study team and relayed their findings to other motorists. Obviously, the team and cameras did have some influence on passing vehicles, but it appeared that the influence was minimal, except on two-lane facilities. On these routes, the rear research vehicle usually had to be maneuvered to within 152 m (500 ft) of the wide load to maintain a view of it. The presence of the research vehicle caused traffic approaching the rear escort vehicle to decelerate and form a queue behind the research vehicle.

Thus, it was impossible to determine all of the rear-end traffic conflicts that would normally be attributed to the wide load. Also, when both brake lights of a vehicle were inoperative, it was not possible to determine whether or not the driver used the brakes.

Another concern expressed during the developmental stage of the project was that the lead research vehicle might retard the normal speed of the wide-load driver and influence the study results. Extensive practice sessions were held before actual data collection to determine whether it was possible to maintain a headway that would not influence the driver of the wide load. The results of the experiments indicated that the lead driver could accurately judge the speed of the load through various roadway geometrics and continuously maintain sufficient distance ahead of the load. The results of the speed data collected during the study also indicated that the lead vehicle did not influence the speed of the wide load (13).

The film data were reduced by using two photooptical analyzers, each equipped with a variable speed advance and stop-action capability. To give full coverage of the vehicle-load interactions, the films from the front and rear cameras were simultaneously projected on the same screen. The conflicts data were recorded from the film by two observers. To reduce observer bias and ensure reliability, extensive training sessions were held. After one week of training, the observers were able to consistently recognize and record the same type and frequency of conflict. During reduction of the film data, conflict counts by each observer were compared for each section of roadway and differences in the data were corrected by reviewing the film. Thus, the variability of the counts due to subjectivity on the part of the observers was minimal.

ANALYSIS

Although the time available for data collection was limited to eight weeks, 6087 km (3782 miles) of wide-load movement were filmed. The distribution of the data-collection effort by type of highway and load size is shown in Table 1. Because of rain, mechanical breakdowns, and other problems, comparison data for the two sizes of units were not available for some routes. Consequently, data for 507 km (315 miles) of travel were eliminated before the statistical comparisons were made.

Before the traffic-conflicts data were analyzed, the speeds of the two sizes of units and the interaction data for each study section were compared. Statistical analyses of these data, given in the study report (13), showed that there were no significant differences. Because the speed and volume data for the two sizes of units were not significantly different for the highway systems studied, it was assumed that any difference in traffic conflicts could be attributed to the width of the load.

The manner in which the traffic conflicts were identified and collected for this study is unique. Consequently, there were no previous data that could have been used to estimate sample size or to serve as a basis for comparing the results obtained in this study. Because there were no previous data, there was no documented mathematical basis for choosing a significance level for testing the differences in conflict counts. For the purpose of this study, a 99 percent confidence level ($\alpha = 0.01$) was used unless otherwise noted. This high confidence level implies a reluctance to reject the null hypothesis unjustly; i.e., large differences in the characteristics of the units were required to reject the hypothesis that there were no differences. A consequence of this approach is that the probability of not rejecting the null hypothesis when it is really false is large unless the deviation from the null hypothesis is large (commonly called a type 2 error). In other words, it was assumed that 3.7-m-wide housing units would continue to be used on Virginia highways and that 4.3-m-wide units would be permitted unless a substantial difference in safety characteristics were found. The only way any error in judgment, if in fact an error occurred, could be reduced would be to increase the sample size. Because of time constraints, it was not possible to extend the data-collection period.

Results of Traffic-Conflicts Analysis

After reduction, the data included 737 conflicts for 3.7-m-wide units and 832 for 4.3-m-wide units. These conflicts were defined for the 13 specific maneuvers shown in Figures 1 through 13. Wherever possible, the conflicts terminology given in the General Motors procedures manual (7) was used. Conflicts were classified as either vehicle or load conflicts. Vehicle conflicts were further classified as being either direct or indirect. A direct vehicle conflict is one that occurs when the driver applies brakes to avoid a collision with the wide load; an indirect vehicle conflict is one that occurs when two or more drivers in the vicinity of the load apply

Table 1. Data-collection summary.

Type of System	3.7-m-Wide Load		4.3-m-Wide Load		Travel Total Filmed (km)	Percentage of Travel Filmed
	No. of Trips	Travel (km)	No. of Trips	Travel (km)		
Interstate	12	816	16	1059	1875	30.8
Primary						
Four-lane divided	30	1279	34	1337	2616	43.0
Four-lane undivided	7	124	9	165	289	4.7
Two-lane	27	503	33	614	1117	18.4
Secondary	12	95	12	95	190	3.1
Total	88	2817	104	3270	6087	100.0

Note: 1 m = 3.3 ft; 1 km = 0.6 mile.

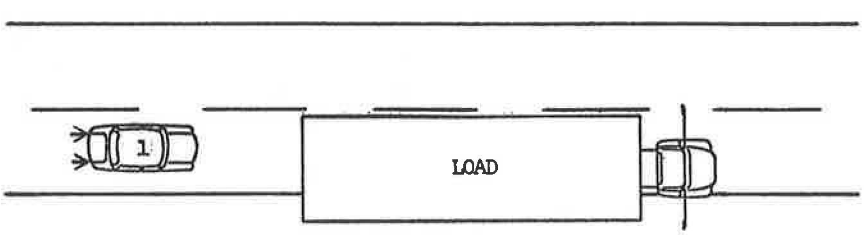

Figure 1. Direct conflict of rear-end vehicle: Vehicle no. 1, which is following the wide load, brakes to avoid collision with the load.

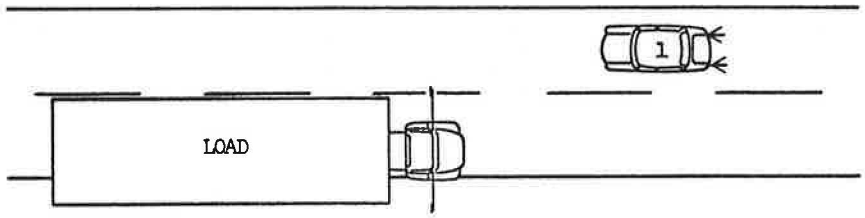

Figure 2. Direct conflict of opposing vehicle: Vehicle no. 1, which is approaching the wide load, brakes to avoid a collision with the load or an adjacent roadside obstacle.

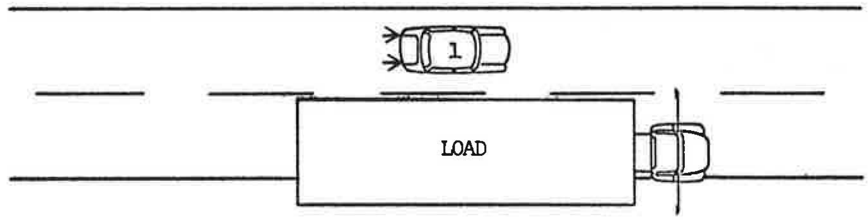

Figure 3. Direct conflict of passing vehicle: Vehicle no. 1, which is passing the wide load, brakes to avoid collision with the load, approaching traffic, or a roadside obstacle.

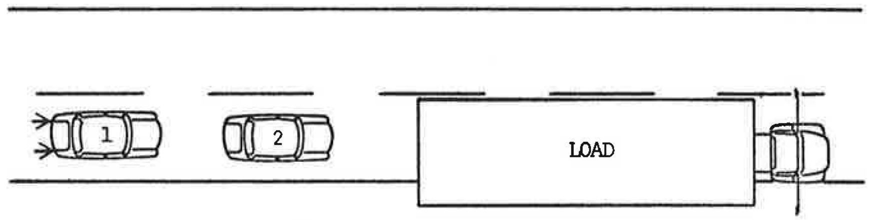

Figure 4. Indirect conflict of nonprevious rear-end vehicle: Vehicle no. 1 brakes to avoid a collision with vehicle no. 2, which is following the wide load.

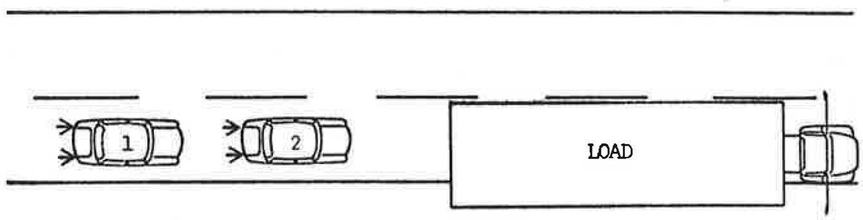

Figure 5. Indirect conflict of previous rear-end vehicle: Vehicle no. 1 brakes in response to vehicle no. 2, which is braking to avoid a collision with the wide load.

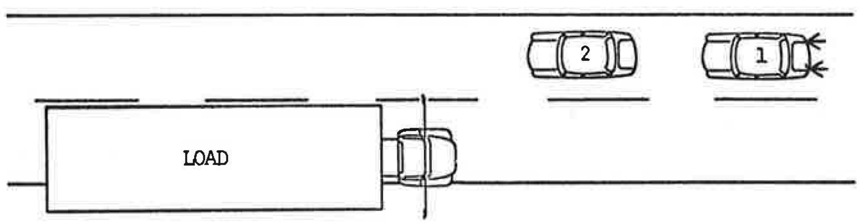

Figure 6. Indirect conflict of nonprevious opposing vehicle: Vehicle no. 1 brakes to avoid a collision with vehicle no. 2, which is approaching the wide load.

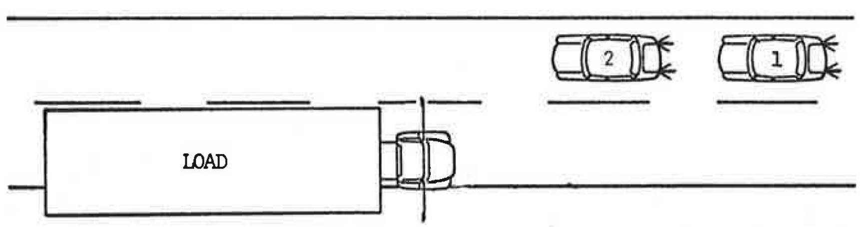

Figure 7. Indirect conflict of previous opposing vehicle: Vehicle no. 1 brakes in response to vehicle no. 2, which is braking to avoid a collision with the wide load or a roadside obstacle.

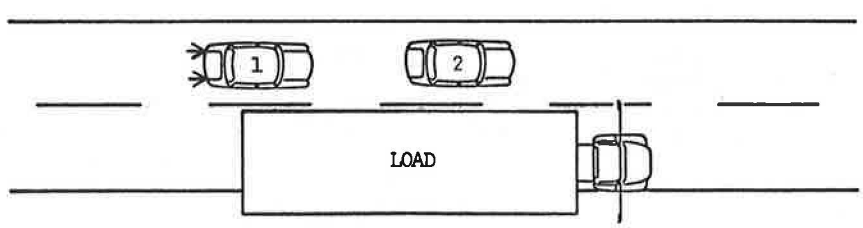

Figure 8. Indirect conflict of nonprevious passing vehicle: Vehicle no. 1 brakes to avoid a collision with vehicle no. 2, which is passing the wide load.

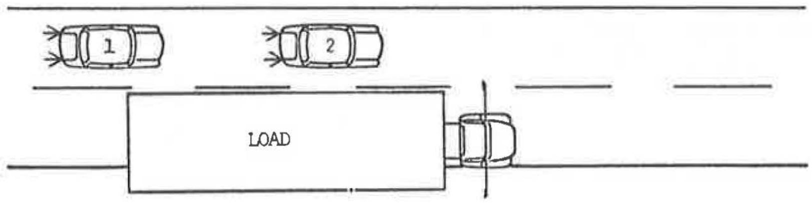

Figure 9. Indirect conflict of previous passing vehicle: Vehicle no. 1 brakes in response to vehicle no. 2, which is braking to avoid a collision with the wide load, opposing traffic, or a roadside obstacle.

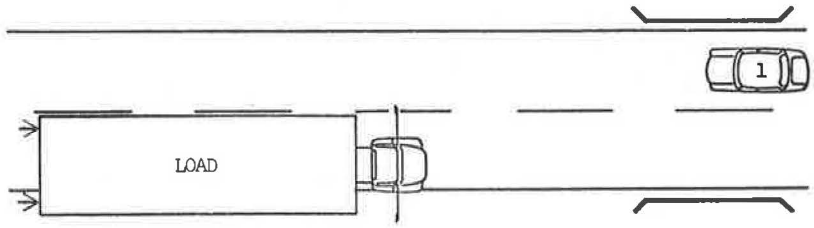

Figure 10. Conflict of load and opposing traffic and narrow structure: Load brakes to avoid collision with a narrow structure and vehicle no. 1.

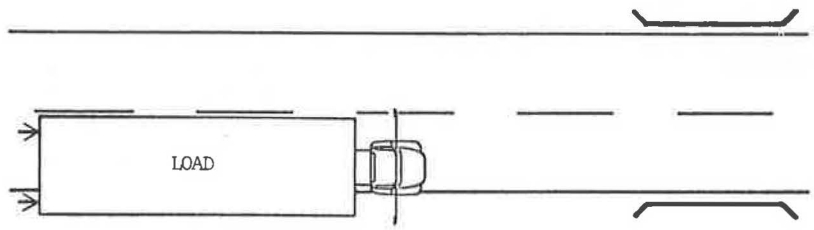

Figure 11. Conflict of load and narrow structure: Load brakes to avoid collision with a narrow structure.

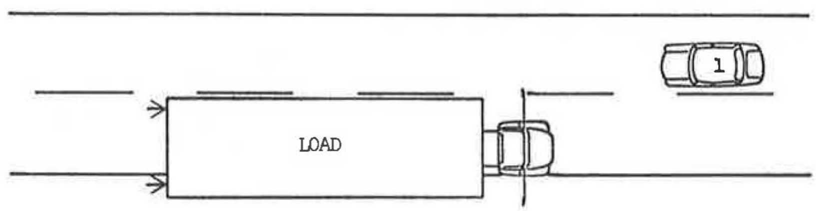

Figure 12. Conflict of load and opposing traffic: Load brakes to avoid collision with vehicle no. 1, which is approaching in the opposing traffic lane.

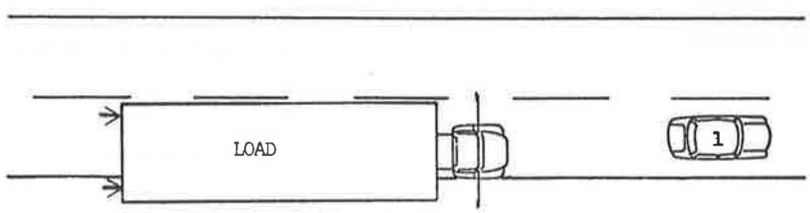

Figure 13. Conflict of load and rear end: Load brakes to avoid collision with vehicle no. 1, which is traveling in the same direction.

brakes to avoid a collision with another vehicle or a roadside obstruction. Conflicts in this latter category were considered to be indirectly caused by or related to the movement of the load.

The types and frequencies of traffic conflicts observed are given in Tables 2 and 3 for the 3.7- and the 4.3-m-wide units, respectively. Although there were frequent vehicle conflicts with the load, there were few load conflicts with other traffic or features of the highway system, e.g., roadside obstructions.

The conflict data in Tables 2 and 3 indicate some interesting relationships among the types of highway systems and the numbers of conflicts. For example, the Interstate system had the smallest number of conflicts for both load widths. The greatest number of conflicts occurred on two-lane primary facilities. The most important types of conflicts on these roads were direct and indirect conflicts of opposing vehicles (Figures 2, 6, and 7). The most frequent type of conflict on four-lane divided routes was the direct conflict of a passing vehicle (Figure 3). This observation can be explained by the fact that the most common vehicle-load interaction on four-lane divided highways is the passing maneuver. The indirect conflicts given in Tables 2 and 3 indicate that wide loads can create hazards for other vehicles without themselves being directly involved. After some cells were combined to obtain samples of sufficient size for each type of highway system, the χ^2 statistic was used to test for differences in the distributions of conflicts between 3.7- and 4.3-m-wide loads. As noted below, the distributions were not disproportionate; i.e., the type and frequency of occurrence of conflicts were not different for the two load widths.

Type of System	χ^2	Significant at $\alpha = 0.01$	df
Interstate	1.20	No	1
Primary			
Four-lane divided	3.77	No	2
Four-lane undivided	6.7×10^{-5}	No	1
Two-lane	8.89	No	3
Secondary	0.49	No	1

The mean number of traffic conflicts recorded for the two load widths by type of highway are compared in Table 4. Although no significant differences were found for each category, there were dramatic differences among categories, e.g., Interstate compared with two-lane primary. However, care should be exercised when making comparisons among groups because these are raw data that should be normalized to account for lengths of roadway sections and traffic volumes.

The effect of section length on number of conflicts was examined by dividing the number of observed conflicts for each test run by the length of the test section to determine the number of conflicts per kilometer, which was termed the traffic-conflicts index. In addition, the effect of traffic volume on number of conflicts was examined by dividing the conflicts index by the number of vehicle interactions. This result was termed the traffic-conflicts rate. The conflicts indices and rates for each type of highway system were then summarized; the results of tests for these measures are given in Tables 5 and 6. As noted, no significant differences were found. The conflicts indices and rates are of practical significance because they permit direct comparison of the hazards of the movement of oversize loads for any given route. For example, the data clearly indicate that such movement is more hazardous on two-lane primary and secondary systems than on Interstate and four-lane highways. Furthermore, because these conflicts indicators were developed for each section of road included in the study, it was easy to identify sections that deviated substantially from the mean. As a general rule, roadways

Table 2. Traffic-conflicts summary: 3.7-m-wide load.

	Vehicle Conflict										Load Conflict				
	Direct			Indirect											
				Rear End		Opposing		Passing							
Type of System	Rear End	Opposing Traffic	Passing	Non-previous	Previous	Non-previous	Previous	Non-previous	Previous	Other	Opposing Traffic and Narrow Structure	Narrow Structure	Opposing Traffic	Rear End	Other
Interstate	2	0	4	0	0	0	0	1	0	0	0	0	0	0	0
Primary															
Four-lane divided	20	0	58	1	0	0	0	7	8	0	0	0	0	2	2
Four-lane undivided	5	3	13	1	0	0	0	2	3	0	0	0	0	3	1
Two-lane	71	309	2	8	2	47	116	0	0	0	1	1	4	1	2
Secondary	0	28	0	0	0	0	0	0	0	1	0	0	8	0	0

Note: 1 m = 3.3 ft.

Table 3. Traffic-conflicts summary: 4.3-m-wide load.

	Vehicle Conflict										Load Conflict				
Direct				Indirect											
				Rear End		Opposing		Passing							
Type of System	Rear End	Opposing Traffic	Passing	Non-previous	Previous	Non-previous	Previous	Non-previous	Previous	Other	Opposing Traffic and Narrow Structure	Narrow Structure	Opposing Traffic	Rear End	Other
Interstate	6	0	10	1	0	0	0	4	3	0	0	0	0	0	1
Primary															
Four-lane divided	24	0	109	6	3	1	4	21	16	0	0	1	0	0	0
Four-lane undivided	4	0	19	1	0	1	0	3	5	0	0	0	0	0	1
Two-lane	44	297	5	7	1	49	145	0	0	0	1	3	3	0	4
Secondary	0	24	0	0	0	0	4	0	0	1	0	0	0	0	0

Note: 1 m = 3.3 ft.

Table 4. Number of traffic conflicts.

	3.7-m-Wide Load			4.3-m-Wide Load					
Type of System	No.	Mean	Variance	No.	Mean	Variance	t-Value	Significant[a]	df
Interstate	10	0.70	1.57	14	1.79	3.19	-1.74	No	24
Primary									
Four-lane divided	23	4.41	19.78	25	6.80	34.79	-1.67	No	46
Four-lane undivided	7	4.43	15.62	9	3.78	21.44	0.30	No	16
Two-lane	27	20.89	992.33	26	21.50	1093.38	-0.07	No	53
Secondary	12	3.08	9.90	12	2.42	4.27	0.61	No	20

Note: 1 m = 3.3 ft.
[a] $\alpha = 0.01$.

Table 5. Traffic-conflicts index.

Type of System	3.7-m-Wide Load No.	Mean	Variance	4.3-m-Wide Load No.	Mean	Variance	t-Value	Significant[a]	df
Interstate	10	0.23	0.13	14	0.72	0.54	-2.14	No	22
Primary									
Four-lane divided	23	2.88	8.67	25	4.89	14.68	-2.04	No	46
Four-lane undivided	7	6.18	25.45	9	3.22	5.75	1.43	No	9
Two-lane	27	18.31	346.52	26	18.26	407.31	0.01	No	52
Secondary	12	10.84	74.15	12	11.05	178.56	-0.05	No	20

Notes: 1 m = 3.3 ft.
Conflicts index is expressed in conflicts per kilometer × 10.
[a] $\alpha = 0.01$.

Table 6. Traffic-conflicts rate.

Type of System	3.7-m-Wide Load No.	Mean	Variance	4.3-m-Wide Load No.	Mean	Variance	t-Value	Significant[a]	df
Interstate	10	0.53	0.80	14	1.09	1.86	-1.21	No	24
Primary									
Four-lane divided	23	7.47	66.92	25	12.12	165.84	-1.51	No	43
Four-lane undivided	7	2.53	5.26	9	1.14	0.44	1.56	No	7
Two-lane	27	92.61	46 900.38	26	37.41	2 019.46	1.30	No	28
Secondary	12	987.61	225 108.02	12	288.04	112 579.04	1.14	No	21

Notes: 1 m = 3.3 ft.
Conflicts rate is expressed in conflicts per vehicle kilometer × 1000.
[a] $\alpha = 0.01$.

Table 7. Linear correlation coefficients: volume and number of conflicts.

Type of System	3.7-m-Wide Load N	r^2	r	Critical r[a]	4.3-m-Wide Load N	r^2	r	Critical r[a]
Interstate	10	0.07	0.27	0.63	14	0.34	0.58	0.53
Primary								
Four-lane divided	23	0.35	0.59	0.42	25	0.49	0.70	0.40
Four-lane undivided	7	0.13	0.37	0.75	9	0.04	0.19	0.67
Two-lane	26	0.94	0.97	0.39	26	0.87	0.93	0.39
Secondary	12	0.34	0.59	0.58	12	0.84	0.92	0.58

Note: 1 m = 3.3 ft.
[a] $\alpha = 0.05$.

that had narrow pavements had high conflict rates. The obvious importance of this finding to the highway manager would be to minimize the movement of wide loads on these routes.

Volume and Conflicts Relationship

Traffic-conflicts data recorded for intersections have been shown to be highly volume-dependent (11, 12). To examine the dependence of the number of conflicts on the number of vehicles encountered during the movement of a wide load, linear correlation coefficients r's and coefficients of determination r^2s were computed; the results are given in Table 7. For the six cases on Interstate and four-lane facilities examined, only three coefficients were statistically significant. However, these coefficients indicate that the conflict-volume relationship is not strong. On the contrary, however, the relationship is highly positive for the two-lane primary system. These results confirm the observations of the data-collection crew, who reported that most vehicles on two-lane roads were involved in a traffic conflict. On divided highways, few vehicles were involved in a traffic conflict with a wide load.

Sample-Size Requirements

The sample size is usually controlled by either time or budget constraints; in this study, it was limited by time. In many studies, the mean and variance can be estimated from previous results and the sample size can be determined before the tests are made. However, for this experiment, there were no previous data or guidelines and there was concern that time constraints would limit the data collected to an amount that would be insufficient for statistical tests. In an attempt to secure as much data as possible within the eight-week data-collection period, two cameras were used on each trip. Thus, after the data were collected and summarized, the adequacy of the sample size for each load width and type of highway was determined by the following procedure.

For the data collected, the size of the sample (number of test runs) was known. A confidence level of 90 percent ($\alpha = 0.10$) was chosen, and the task was to determine the sample error. The procedure is illustrated in the example below taken from the 10 samples of 3.7-m-wide load movement on the Interstate system shown in Table 4.

The sampling error is obtained from Equation 1,

$$E = tv/\sqrt{N} \quad (1)$$

where

E = sampling error (percent),
t = sample risk (for $\alpha = 0.10$ with 9 degrees of freedom, $t_{0.95} = 1.83$),
v = variation coefficient (percent) = 100 (standard deviation of sample/sample mean), and
N = sample size.

For the 3.7-m-wide load on the Interstate system,

$$E = 1.83\ [100 \times (1.253/0.70)]/\sqrt{10} = 104 \text{ percent}$$

Therefore, it can be concluded with 90 percent confidence that the mean number of conflicts per test run for a 3.7-m-wide load on the Interstate system is included in the interval between 0 and 1.4.

This procedure was used to determine sample-size errors for the numbers of conflicts and the conflicts indices and rates. The results are given in Table 8. The magnitude of the errors generally indicates that it

Table 8. Computed errors in sample sizes.

Type of System	3.7-m-Wide Load No. of Conflicts	Conflicts Index	Conflicts Rate	4.3-m-Wide Load No. of Conflicts	Conflicts Index	Conflicts Rate
Interstate	104	95	97	48	48	59
Primary						
Four-lane divided	36	37	39	30	27	36
Four-lane undivided	66	60	67	76	46	36
Two-lane	50	33	77	52	37	40
Secondary	53	41	51	44	63	60

Notes: 1 m = 3.3 ft.
Errors are expressed as percentages.

Table 9. Comparison of accident and traffic-conflicts data: 3.7-m-wide loads.

Type of System	1969 Accidents No.	Percentage of Total	1976 Conflicts Data No.	Percentage of Total No.	Travel (km)	Percentage of Total Travel
Interstate	3	13	7	1	673	26
Primary						
Four-lane divided	7	29	98	13	1152	45
Four-lane undivided	2	8	31	4	124	5
Two-lane	9	37	564	77	531	20
Secondary	3	13	37	5	95	4
Total	24	100	737	100	2575	100

Note: 1 m = 3.3 ft; 1 km = 0.6 mile.

would be desirable to collect a larger number of samples. One of the recent criticisms of the traffic-conflicts technique, as applied to intersections, was that a large number of observations are needed to detect changes in numbers of conflicts at a high confidence level (12). The data given in Table 8 tend to support that comment.

For most traffic experiments, large sample sizes are not practical. The data collected for the wide-load study are probably as comprehensive as can be obtained by most state highway agencies. However, a high statistical confidence level can be achieved only by taking considerably more data. For example, for the case of the conflicts recorded for the 3.7-m-wide load on the Interstate system, 1073 test runs would have been required to reduce the sample error to 10 percent (assuming a constant variance-to-mean ratio of 2.2 and a confidence level of 90 percent). A sample size of this magnitude would seldom, if ever, be economically feasible for any traffic study. Furthermore, a reduction of the confidence level does not substantially reduce the number of samples required.

In most cases, the need for large sample sizes can be attributed to the relatively small number of conflicts and the large sample variance. Because of the large sample-size errors computed for the conflicts data, the results of any statistical comparisons of the data are questionable. Furthermore, because the increases in sample sizes necessary to increase the confidence in the results are extraordinarily large, the use of traffic conflicts for the assessment of the hazards of the movement of wide loads is questionable. However, the results of the statistical tests must be interpreted in light of the practical value of the information obtained. The use of accident data as an alternative was not possible because only a few accidents involving 3.7-m-wide units have been reported and 4.3-m-wide units were not allowed in Virginia. The conflicts data were useful for identifying the nature and frequency of hazards imposed on motorists by the movement of wide loads. The data also clearly indicated that the hazards were much greater on two-lane roads than on four-lane divided highways. Even if the sample size could be increased, it is doubtful that any new or different hazards would be found. Thus, the conflicts technique provided more detailed and useful information than conventional accident records could supply. For these reasons, the technique is a useful measure for evaluating highway safety.

The decision to permit or prohibit 4.3-m-wide units was based not only on the conflicts data but also on analyses of other data recorded in conjunction with the conflicts. These data included length and frequency of queues, vehicle passing times, encroachments, lateral placements, and other traffic and safety measures.

Conflicts and Accident Relationship

Because of the scarcity of accident data for oversize units, it is not possible to determine whether there is a relationship between traffic conflicts and accidents. No accidents involving the oversize loads occurred during the study. As the existing traffic-records system does not permit computer identification of wide-load accidents, little data were available. However, an extensive manual search of the Virginia records indicated that in 1969 mobile homes were involved in 24 accidents (2). In these accidents, there were no fatalities; six persons were injured and property damage amounted to $17 500. Although exposure (vehicle kilometers of travel) information for the accident data is not available, a rough comparison of the 1969 accident data and the 1976 conflicts for 3.7-m-wide loads is given in Table 9. Although definite conclusions cannot be formulated, it is interesting that the majority of accidents occurred on two-lane primary and secondary systems, where, according to the conflicts data, the hazards associated with the movement of wide loads are greatest.

Future Applications

Any measure for the evaluation of traffic or safety factors should be judged in terms of its advantages and disadvantages. The large sample size required and the cost of collecting and reducing film data indicate that the traffic-conflicts technique, as applied to the assessment of the hazards of vehicles in motion along the highway, may not be an efficient tool for widespread use by most highway agencies. However, in the absence of accident reports, the technique is useful for the identification of the type and frequency of hazards encountered by vehicles in motion. Its primary advantages are (a) the systematic manner it provides for observing and recording hazards; (b) the more frequent occurrence of conflicts than of other events for measuring safety, e.g., accidents and near misses; (c) the short period of time required to collect the data; and (d) the fact that environment-vehicle-driver data recorded during a conflicts study provide a more exact relationship among these variables than that which can be obtained from a conventional accident analysis.

There are numerous highway-safety problems in which the conflicts technique can be used to provide a better measure of safety than can accident data. For example, the hazards associated with the use of such items as recreational vehicles, trucks, and mowing and centerline-painting machines could be identified by using the conflicts technique.

The following guidelines are offered to potential users of the conflicts technique.

1. A pilot study should be conducted to determine the relative types and frequencies of the hazards associated with the problem under consideration. A definition

should be formulated, and the conflicts should be classified in accordance with the observed hazards. The data-collection procedure, as well as other measures applicable for use in evaluating traffic and safety factors, should be developed.

2. A standard should be chosen as a basis for comparison with the results of the experimental condition, e.g., 3.7-m-wide loads compared with 4.3-m-wide loads.

3. An estimation of the errors in sample size should be made based on the data collected and the confidence level required, and the results should be interpreted in recognition of factors such as staff limitations and time constraints.

CONCLUSIONS

Based on an evaluation of the traffic-conflicts technique as applied to the examination of the hazards of oversize loads in motion along the roadway, the following conclusions are offered.

1. The traffic-conflicts technique can be adapted to a wide range of uses.
2. Hazards associated with moving oversize loads can be identified in a short period of time by using the conflicts technique. (Accident data, which require a long time to develop, could not be used to assess the hazards imposed by wide loads on other traffic.)
3. There are no apparent differences between the safety aspects of 3.7-m-wide loads and those of 4.3-m-wide loads in terms of the types or frequencies of conflicts observed.
4. The movement of wide loads is significantly more hazardous on two-lane facilities than on four-lane divided highways.
5. Traffic conflicts on two-lane highways are extremely volume dependent; however, on divided highways, the relationship is not strong.
6. It may not be practical to collect the large amount of conflicts data necessary to establish a high degree of confidence in the results.
7. Despite the problems of sample size, the conflicts technique is useful in assessing the relative hazards associated with the movement of wide loads on a variety of highway systems.
8. Because of the scarcity of accident data, no relationship between traffic conflicts and accidents for wide loads can be determined.

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