U.S. Department of Transportation
Federal Highway Administration

Larger Dimensioned Vehicle Study

Final Report

U.S. Department of Transportation
Federal Highway Administration
Office of Highway Information Management

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Larger Dimensioned Vehicle Study

Executive Summary

The purpose of the Larger Dimensioned Vehicle Study (LDVS) was to compare the accident experience of single trailer combination trucks versus multi-trailer combination trucks. The LDVS began in 1984 in response to the Surface Transportation Assistance Act (STAA) of 1982 in which tractor-trailer trucks with larger dimensions were permitted to operate in all States on the Interstate and certain other highways.

The LDVS focused on the issue of the relative safety of multi-trailer trucks versus single trailer trucks. All other vehicles were lumped together for comparison purposes. There have been other studies which also compared single and multi-trailer trucks. The distinguishing features of the LDVS were the collection of exposure data by functional class of highway and detailed data on highway geometrics at the accident site.

Thirteen States participated in the LDVS over the data collection period of 1983 to 1991 although only four States provided data for a majority of those years: Iowa, Kansas, Missouri, and Utah. This greatly limited the ability to generalize the results. An Interim Report was produced in 1987 covering data up to 1985. This Final Report extends the Interim Report to the full data collection period.

Involvement rates by functional class of highway were derived from the data for single trailer trucks, multi-trailer trucks, and all other vehicles together. The overall rates per 100 million vehicle-miles of travel were as follows:

	Fatal Involvement Rate	Non-Fatal Involvement Rate
Single Trailers	2.44	31.46
Multi Trailers	2.08	25.15
Other Vehicles	2.32	81.51
All Vehicles	2.33	76.14

One criticism of this kind of rate is that it ignores the different distributions of travel by functional class that the various vehicle types have. For example, most multi-trailer travel is on the Interstate and other higher functional systems. To compensate for this, the involvement rates were adjusted to make the percent of travel on each functional class the same for every vehicle type. Since the focus here is on comparing single and multi-trailer vehicles, the travel distribution for combination trucks was added together and used for the adjustment. (See Appendix B for further explanation.) The adjusted rates were as follows:

	Fatal Involvement Rate	Non-Fatal Involvement Rate
Single Trailers	2.43	31.28
Multi Trailers	2.44	28.02
Combination Trucks	2.43	31.08

Thus multi-trailer trucks have a lower fatal involvement rate than single trailer trucks for their current distribution of travel by functional class, but a similar rate would result if they had the same distribution of travel.

Involvement rates for single and multi-trailer trucks were found to be similar for the various types of access control, number of lanes, lane width, median width, and shoulder width. Some difference was found on urban roads when median type and shoulder type were considered. Multi-trailer trucks had fewer of their involvements when there was a median barrier. Multi-trailer trucks had more of their involvements when there was a stabilized shoulder, and single trailer trucks had more of their involvements when there was a surfaced shoulder.

The most significant geometric characteristics were the curvature and the gradient. All combination trucks had a greater percentage of their involvements on roads with curvature or gradient greater than zero. Multi-trailer trucks compared with single trailer trucks had a somewhat greater percentage of their involvements on curves or gradients greater than zero.

Introduction

With the enactment of the Surface Transportation Assistance Act (STAA) of 1982, tractor-trailer trucks with dimensions and configurations previously prohibited from operating within certain States were permitted to operate in all States on Interstate highways and on Federal Aid Primary highways designated by the U.S. Secretary of Transportation. These designated highways, taken together, are referred to as the National Network. In some States additional highways have been identified by the States as being open to the same trucks as are allowed on the National Network. This latter group of State designated roads along with roads on the National Network will be referred to as the Large Truck System (LTS).

The truck characteristics affected by the STAA included an increase of width from 96 to 102 inches, and trailer lengths of up to 48 feet or longer, depending on State restrictions, unrestricted by overall vehicle length. Furthermore, combination trucks consisting of a tractor, semitrailer and full trailer (double bottom or twin trailers) where trailers are 28 feet (28 1/2 feet if allowed by the State) were permitted to operate on the National Network in all States.

In a number of States at the time the National Network was identified, concerns were expressed to the FHWA that these large vehicles would result in increased numbers of accidents and that they should be prohibited from operating on roads with geometrics that were deemed marginal or not equivalent to the present standards for such highways. In response to these concerns, the FHWA initiated the Larger Dimensioned Vehicle Study (LDVS) in 1984 to monitor the operation of combination trucks on the National Network.

One concern was that the safety of multi-trailer trucks operating on a limited basis primarily on the Interstate system reflects the high-level standard of design of the Interstate system which would not apply to lower functional classes of highway. Another concern was that multi-trailer trucks operate primarily in rural areas but are unsafe on higher-volume urban areas.

An Interim Report on the LDVS was produced in 1987 covering data collected up to 1985 (8). This Final Report extends the Interim Report to the full data collection period of 1983 to 1991. In accordance with a recommendation of the FHWA Truck Travel Data Conference (9), this Final Report concludes the LDVS. That Conference recommended using case studies to address future safety issues of particular vehicle configurations.

The Data Base

In response to FHWA's request, the following States provided data for this study for the years designated:

State	Data Years
Illinois	1984
Iowa	1984 - 1991
Kansas	1986 - 1991
Missouri	1983 - 1991
Nebraska	1986
Nevada	1983 - 1984
New Jersey	1985
New York	1985 - 1988
North Dakota	1986
Utah	1984 - 1989
Washington	1984 - 1985
West Virginia	1984 - 1986
Wisconsin	1984 - 1986

Other data sets were received from these and other States such as California, Pennsylvania and New Mexico which were not in formats directly applicable to the present study.

Appendix A contains the reporting format and data definitions used for the data requested by the FHWA. The information was divided into vehicle-miles of travel (VMT) and accident data by route, and detailed information on individual accident sites. The States were to use their normal collection practices in gathering the data. In some instances the participating States increased their travel monitoring in order to provide wider coverage of the LTS. Also, in some States accident reporting forms were augmented to included the specific reporting of multitrailer vehicles. In other States, information on single and multitrailer combination trucks in accidents was obtained by special editing of the narrative portion of the police accident reports.

The portion of highways monitored ranged from all to a subset of the LTS in each State. It cannot be overemphasized that a critical element in the data reporting is VMT by vehicle type by route. This data element was a major factor in a State's determination of how much of the LTS it could reasonably monitor.

In some States the vehicle classification data from which the VMT estimates by vehicle type are based are extensive and/or stable enough so as to allow reporting on all LTS mileage. In other States, vehicle classification data is limited or the variation in the traffic mix is felt to be so changeable that only selected links of the LTS would have the needed VMT information and therefore only these were monitored for this study. Since the higher functional classes of highways generally are monitored more often than the lower functional classes, the resulting VMT estimates are probably more accurate for the higher systems than for the lower systems.

The route level information included VMT by vehicle type over the reporting period as well as the total number of fatal or injury producing accidents, the total number of fatalities, the total number of nonfatal injuries, and the total number of vehicle involvements.

The accident site information was reported for each fatal or nonfatal injury accident occurring during the reporting period involving a combination truck with a single trailer or multiple trailers. In addition to highway geometrics, the site level information also included the total number of vehicles involved, the number of single trailer combination trucks involved, the number of multi-trailer trucks involved, the number of deaths, and the number of nonfatally injured persons.

The reader should note that although the 1982 Act allowed for a number of potential changes to the configuration of combination trucks, this study focuses exclusively on the differences in accident histories between single trailer and multi-trailer vehicles. All other vehicles are lumped together for comparison purposes. Other studies have compared single and multi-trailer trucks without reaching a definitive conclusion (see Bibliography). The distinguishing features of the LDVS are the collection of exposure data by functional class of highway and detailed data on highway geometrics at the accident site.

The multi-trailer vehicles in the data base are primarily conventional (Western) doubles, that is, trucks with twin trailers both of which are 26 to 28 feet long. Of the States included in this study Nevada, North Dakota, Utah, and Washington allow longer combination vehicles (LCVs) which are multi-trailer trucks either with one trailer longer than 28 feet or with three trailers. Kansas and New York also allow LCVs but only on turnpikes. Thus some LCVs are represented in the data base, but this should not be considered an LCV study.

After receipt of a State's data, a computerized editing process was initiated. This included checks for logical consistency, i.e., the total number of accidents on a route at least equaled the number of accident site records reported, and geometric values were tested using the criteria from the Highway Performance Monitoring System (HPMS) routines. When the data items were found to pass the edits, tables were run for each State showing accidents, vehicle involvements, and injuries as fatal or nonfatal for the various functional highway classes, as well as the vehicle involvement rate.

In addition to developing standard reports on a State-by-State basis, the vehicle involvement information for each of the States was aggregated into a single file and reported as a summary of all the data available nationally. This national summary aggregates travel and accident information from the participating States only. A national summary shows a value for travel and involvements for all reported mileage in the participating States, values by functional class of highway, and for each individual State by functional system.

Accidents and Involvements

Throughout this report it is important to understand the distinction between accident rates and vehicle involvement rates. In any accident, a number of vehicles may be involved. Commonly an accident may be typified by a particular vehicle or accident characteristic. For example, in an accident involving an automobile and a truck, the analyst may assume that it is a truck accident. The problem with this approach is that if we were to calculate accident rates, the accident might be attributed wholly to trucks simply because one was involved. This approach implicitly assumes that an accident is attributable to or was caused by a particular vehicle type simply because it was present in the accident.

For this reason it is often preferable to describe accidents in terms of vehicle involvements and involvement rates. Involvements are the number of vehicles of a given type that are part of an accident. A single accident involving two automobiles and one truck would be interpreted as two automobile involvements and one truck involvement. If a death resulted in the accident, each vehicle would be classed as having a fatal involvement. If a truck consisted of a power unit plus two or more trailers, it would still be counted as a single truck involvement since the power unit and trailing units are intended to operate as a single vehicle.

Using involvements for rate calculations allows us to attribute each vehicle type with participation in the accident in proportion to the number of vehicles of a given type that were present. In the previous example the car-truck accident would be interpreted as one car involvement and one truck involvement.

The method of analysis used in this report was to compare accidents involving multi-trailer trucks to accidents on similar highway systems and States involving single trailer combination trucks. A multi-trailer accident is defined as one involving a multi-trailer vehicle. A single trailer accident is defined as one involving a single trailer combination truck and no multi-trailer trucks. This comparison sought to determine whether there were discernible differences between the geometric conditions or patterns of accident type for single trailer versus multi-trailer accidents.

Involvement rates are given as the number of involvements for a given vehicle type per 100 million miles of travel by that vehicle type. For example, if a vehicle type had one fatal involvement in 25 million miles of travel, its fatal involvement rate would be four. For ease of comparison involvement rates were also normalized by dividing them by the overall rate. This makes the average rate equal to one.

Involvement rates are sometimes criticized for ignoring the different distributions of travel by functional class that the various vehicle types have. For example, most multi-trailer travel is on the Interstate and other higher functional classes. To compensate for this, the involvement rates may be adjusted to make the percent of travel on each

functional class the same for every vehicle type (2). Appendix B describes this approach in detail.

It was not possible to compute involvement rates for the different geometric characteristics because there is no exposure data by highway geometry. The approach taken was to examine the distribution of accidents by geometric characteristic for each vehicle type to see whether or not a disproportionate share took place at a certain type of site.

Summary of Findings - Involvement Rates

What follows is a descriptive analysis of the data base focusing on a comparison of single and multi-trailer vehicles. Because of the limitations of the data, no error estimates are given. The tentative nature of the data needs to be borne in mind when considering the results.

The LDVS Overview in Table 1 shows that the overall involvement rate for multi-trailer trucks is slightly lower than that for single trailer trucks for both fatal and nonfatal injury accidents. This rate ignores the different distributions of travel by functional class that the various vehicle types have. To compensate for this, the involvement rates were adjusted to make the percent of travel on each functional class the same for both vehicle types of interest. See Appendix B for further explanation of the adjustment process used. The adjusted rates show single and multi-trailer vehicles having similar involvement rates.

The LDVS Summary in Table 2 breaks out rural and urban interstate from the other functional systems. These four functional class groups will be used in much of the analysis that follows. In a detailed breakdown by functional class (Tables 3 and 4), the rates for both single trailer trucks and multi-trailer trucks increase in going from the higher systems (Interstate or other arterials) to the lower systems (collectors or locals).

Other findings are presented as graphs in the figures given. Vehicle travel in the data base (Figure 1) shows that single trailer trucks account for 10 percent of the total travel and multi-trailer trucks account for less than 1 percent. Travel by functional class groups (Figure 2) shows that combination trucks have a disproportionately large share of their travel on the rural Interstate compared with other vehicles.

Fatal involvements are shown in Figures 3 and 4. The distribution by functional class group (Figure 5) shows that a large share of fatal involvements are off the Interstate in rural areas for all vehicle types.

The fatal involvement rates displayed in Figure 6 are all similar with multi-trailer vehicles having the lowest overall rate. This changes in Figure 7 where multi-trailer

trucks have a very high involvement rate off the Interstate in urban areas. Single trailer trucks show a similar but less pronounced pattern.

Figure 8 shows the fatal accident rates (not involvement rates) from the Highway Performance Monitoring System during the years 1983 to 1989 (6) for comparison. The pattern of rates by functional class group is similar to that of the Other Vehicles in the previous figure as would be expected.

As explained above, the involvement rates were adjusted to the same distribution of travel over all functional systems (Figure 9). The result was that multi-trailer trucks have a better unadjusted rate but a similar adjusted rate compared with single trailer trucks.

The normalized fatal involvement rates by functional class group in Figure 10 show little difference except for the lower rates for combination trucks on the rural Interstate. More detailed graphs are given in Figures 11 to 14. The general trend is that the lower the functional class, the higher the involvement rate with the combination truck rates increasing more than other vehicles. However, the lower functional classes have little exposure data for combination trucks. Accordingly, subsequent graphs will focus on the Interstate and all Other (i.e., non-Interstate) Rural and Urban functional class groups.

Non-fatal injury involvements are shown in Figures 15 and 16. Vehicles other than combination trucks had a greater proportion of non-fatal involvements (95.4%) than fatal involvements (88.9%) as would be expected from the greater momentum of combination trucks. Non-fatal involvements by functional class group (Figure 17) reflect the distribution of travel.

Non-fatal involvement rates are shown in Figure 18. Vehicles other than combination trucks have non-fatal involvement rates substantially higher than those for combination trucks. Involvement rates are adjusted as before in Figure 19. Again, the multi-trailer vehicles have a better unadjusted rate but a similar adjusted rate compared with single trailer trucks. The normalized rates by functional class group in Figure 20 show the same pattern as Figure 18.

Figure 21 shows that the highest rates for all vehicle types are in urban areas off the Interstate. The HPMS accident rates (not involvement rates) in Figure 22 show a similar pattern except for the lower rates on the urban Interstate.

The rural and urban rates in Figures 23 to 26 show that non-fatal rates generally increase for the lower functional classes as they did with fatal rates. The high rural minor collector rate for single trailers is affected by the low exposure data available. The relatively high urban other principal arterial rate for multi trailers is more significant.

Summary of Findings - Geometrics

The site records were aggregated to show the percent of involvements (either fatal or non-fatal) by vehicle type to see if any geometric characteristic was associated with a disproportionate share of involvements. The characteristics chosen matched those in the HPMS data base. The general result was that single and multi trailer trucks exhibited similar patterns.

Three types of access control were considered: full (interchanges only), partial (some at-grade crossings), and none. As Figure 27 shows, full access control had the highest percent of combination truck involvements reflecting their predominant travel on the Interstate. The higher percent of involvements for other vehicles with no access control reflects their greater travel in lower functional classes and the inherent dangers of high access roads. Figures 28 to 31 continue these patterns on the functional class groups.

In Figure 32 the lane width involvements were grouped by less than 12 feet and 12 feet or more. No significant pattern emerged, no doubt because of the greater travel on higher functional classes.

Figures 33 to 37 show the involvements by number of lanes. Again the patterns reflect the travel distributions and the geometrics of the functional class groups.

Involvements by shoulder type are shown in Figures 38 to 42. The types considered were none, earth (with or without turf), surfaced (with concrete or bituminous material), stabilized (gravel or a combination of surfaces), and curbed. Patterns for single and multi trailers were similar. Note the high percent of combination truck involvements with no shoulder.

Involvements by right shoulder width are shown in Figures 43 to 47. The pattern is similar for all vehicle types: the lower the shoulder width the higher the percent of involvements with the caveat that most shoulders on the Interstate are greater than 8 feet wide.

Figures 48 to 52 show involvements by the median types curbed, positive barrier, unprotected, and none. Again the patterns are similar for the different vehicle types. However, note the low number of involvements of multi-trailer trucks with a curbed median on the urban Interstate (Figure 51).

Median width (including shoulders, if any) is shown in Figures 53 to 57. The patterns for single and multi-trailer trucks are again similar.

Involvements by degree of curve are shown in Figures 58 to 62 for none, between 0 and 2.5 degrees, at least 2.5 but less than 5.5 degrees, at least 5.5 but less than 14 degrees, and 14 or more degrees. Combination trucks had less of their involvements

than other vehicles on roads with no curvature. That is, combination trucks had a greater percentage of their involvements on roads with positive curvature. This effect was more pronounced for multi-trailer trucks.

Involvements by percent of grade are shown in Figures 63 to 67 for level grade, between 0 and 0.5 percent, at least 0.5 but less than 2.5 percent, at least 2.5 but less than 4.5 percent, and 4.5 or more percent grade. The results paralleled the effect of curvature. Gradient was a much greater factor for combination trucks than for other vehicles. Multi-trailer trucks had a greater percent of their involvements than single trailer trucks on non-level grades for all functional class groups.

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Appendix A

File Format for Route Data (Card1)

Field	Name	Length	Position	Description
1	STATE	2	1-2	State FIPS code; see HPMS Field Manual, Appendix A
2	BEGMO	2	3-4	Beginning month (1-12)
3	BEGYR	2	5-6	Last 2 digits at start of reporting period
4	ENDMO	2	7-8	Ending month (1-12)
5	ENDYR	2	9-10	Last 2 digits at end of reporting period
6	FUNC	2	11-12	Functional class code; see Chapter IV of the HPMS Field Manual
7	SIGNED	5	13-17	The commonly used signed designation of the route
8	ST4	8	18-25	Single trailer combination VMT in 1000's
9	MT5	7	26-32	Multi-trailer combination VMT in 1000's
10	AOV	8	33-40	All other vehicle VMT in 1000's
11	ACFAT	3	41-43	Total fatal accidents for all motor vehicles, not just those with trucks involved
12	ACINJ	5	44-48	Total non-fatal injury accidents for all motor vehicles, not just those with trucks involved
13	FATALS	3	49-51	Total fatalities for all motor vehicle accidents, not just those involving trucks
14	INJURY	5	52-56	Total non-fatally injured persons for all motor vehicle accidents, not just those with trucks involved

File Format for Route Data (Card1) - Continued

Field	Name	Length	Position	Description
15	STFAT	3	57-59	Total single trailer combination truck fatal accident vehicle involvements
16	STINJ	5	60-64	Total single trailer combination truck non-fatal injury vehicle involvements
17	MTFAT	3	65-67	Total multi-trailer combination truck fatal accident vehicle involvements
18	MTINJ	5	68-72	Total multi-trailer combination truck non-fatal injury vehicle involvements
19	AOVFAT	3	73-75	All other fatal vehicle involvements: total number of vehicles involved in fatal accidents and not reported as a single or multi-trailer combination truck involvement
20	AOVINJ	5	76-80	All other non-fatal vehicle involvements: total number of vehicles involved in non-fatal injury accidents and not reported as a single or multi trailer combination truck involvement
21	LENGTH	6	81-86	Route length reported to thousandths of a mile with decimal point assumed; see HPMS Field Manual, Chap. IV, Item 23
22	CARD	1	87	Value is 1

File Format for Accident Site Data (Card2)

Field	Name	Length	Position	Description
1	STATE	2	1-2	State FIPS Code as found in Appendix A of the HPMS Field Manual
2	BEGMO	2	3-4	Beginning month (1-12)
3	BEGYR	2	5-6	Last 2 digits at start of reporting period
4	ENDMO	2	7-8	Ending month (1-12)
5	ENDYR	2	9-10	Last 2 digits at end of reporting period
6	FUNC	2	11-12	HPMS Functional Class Code as found in Chapter IV of the HPMS Field Manual
7	SIGNED	5	13-17	The commonly used signed designation of the route
8	COUNTY	3	18-20	3-digit FIPS county code
9	TRAFWAY	12	21-32	Trafficway milepoint or other code used to specify the portion of the route on which the accident occurred; see HPMS Chapter IV, Item 7
10	MONTH	2	33-34	Month of accident (1-12)
11	DAY	2	35-36	Day of month of accident (1 to 31)
12	TOTVEH	2	37-38	Total number of vehicles involved; include all motor vehicles involved in each accident
13	ST4	1	39	Number of single trailer trucks involved
14	MT5	1	40	Number of multi-trailer trucks involved
15	ACINJ	2	41-42	Number of non-fatally injured persons
16	ACFAT	2	43-44	Number of fatally injured persons

File Format for Accident Site Data (Card2) - Continued

Field	Name	Length	Position	Description
17	LNUM	2	45-46	Number of through lanes; see HPMS Field Manual, Chapter IV, Item 22
18	LWIDE	2	47-48	Lane width to the nearest foot; see HPMS Chapter IV, Item 43
19	STYPE	1	49	Shoulder type; see HPMS Field Manual, Chapter IV, Item 44
20	SWIDER	2	50-51	Right shoulder width; see HPMS Chapter IV, Item 45
21	SWIDEL	2	52-53	Left shoulder width; see HPMS Chapter IV, Item 45
22	MTYPE	1	54	Median type; see HPMS Chapter IV, Item 46
23	MWIDE	2	55-56	Median width; see HPMS Chapter IV, Item 47
24	AC	1	57	Access control; see HPMS Chapter IV, Item 42
25	CURVE	3	58-60	Degree of curvature in vicinity of accident to the nearest tenth degree with leading zeros
26	GRADE	2	61-62	Percent of grade in vicinity of accident to the nearest tenth of a percent with leading zeros (code 0.2 as 02)
27	SKID	2	63-64	Skid number to the nearest whole number as measured by a locked wheel skid trailer per ASTM E274
28	TRIPLES	1	65	Number of triple trailer combination trucks involved
29	FARS	4	66-69	NHTSA Fatal Accident Reporting System number, if available
30	BLANK	10	70-79	Not used
31	CARD	1	80	Value is 2

Appendix B

Adjustment of Involvement Rates

In order to compare the involvement rates of different vehicle types in a fair manner they were adjusted to give each vehicle type the same distribution of travel over functional systems (cf. Figure 2). Here is a description of the method used for adjusting involvement rates:

Given

Involvements by vehicle class (VC) and functional class (FC) = $Inv_{VC,FC}$

VMT by VC and FC = $VMT_{VC,FC}$

VMT by FC = $VMT_{FC} = \Sigma_{VC}\ VMT_{VC,FC}$

VMT by VC = $VMT_{VC} = \Sigma_{FC}\ VMT_{VC,FC}$

Total VMT = $VMT = \Sigma_{VC}\ \Sigma_{FC}\ VMT_{VC,FC}$

Involvement Rates by VC and FC = $Inv\_Rate_{VC,FC} = Inv_{VC,FC} / VMT_{VC,FC}$.

Then

Adjusted VMT by VC and FC = $Adj\_VMT_{VC,FC} = VMT_{VC} * (VMT_{FC} / VMT)$

Adjusted Involvements by VC and FC = $Adj\_Inv_{VC,FC}$

$= Inv\_Rate_{VC,FC} * Adj\_VMT_{VC,FC}$

$= Inv_{VC,FC} * (VMT_{VC} * VMT_{FC}) / (VMT_{VC,FC} * VMT)$

Adjusted Involvement Rates = $Adj\_Inv\_Rate_{VC} = Adj\_Inv_{VC} / Adj\_VMT_{VC}$

$= \Sigma_{FC}\ Adj\_Inv_{VC,FC} / VMT_{VC}$

$= \Sigma_{FC}\ (Inv_{VC,FC} / VMT_{VC,FC}) * (VMT_{FC} / VMT)$

$= \Sigma_{FC}\ Inv\_Rate_{VC,FC} * (VMT_{FC} / VMT)$.

The adjusted rates may be renormalized:

$Norm\_Adj\_Inv\_Rate_{VC} = Adj\_Inv\_Rate_{VC} / \Sigma_{VC}\ Adj\_Inv\_Rate_{VC}$

$= \Sigma_{FC}\ (Inv\_Rate_{VC,FC} / \Sigma_{VC}\ Adj\_Inv\_Rate_{VC}) * (VMT_{FC} / VMT)$.

As an example of adjusting and normalizing involvement rates consider two vehicle types and two functional classes with the following involvements and exposures:

Involvement Rates	Class 1	Class 2	Total
Vehicle A	20/5 = 4.0	10/15 = 0.7	30/20 = 1.5
Vehicle B	22/55 = 0.4	248/25 = 9.9	270/80 = 3.4
Total	42/60 = 0.7	258/40 = 6.5	300/100 = 3.0

Divide these by the overall rate of 3.0 to get the normalized rates which will always have an overall rate of 1.0:

Normalized Rates	Class 1	Class 2	Total
Vehicle A	4.0/3.0 = 1.3	0.7/3.0 = 0.2	1.5/3.0 = 0.5
Vehicle B	0.4/3.0 = 0.1	9.9/3.0 = 3.3	3.4/3.0 = 1.1
Total	0.7/3.0 = 0.2	6.5/3.0 = 2.2	3.0/3.0 = 1.0

For the adjusted rates multiply the involvement rates by the proportion of total travel for each functional class. So multiply the Class 1 rates by 60/100 = 0.6 and the Class 2 rates by 40/100 = 0.4:

Adjusted Rates	Class 1	Class 2	Total
Vehicle A	0.6*4.0= 2.4	0.4*0.7 = 0.3	2.4+0.3= 2.7
Vehicle B	0.6*0.4= 0.2	0.4*9.9 = 4.0	0.2+4.0= 4.2
Total	0.6*0.7= 0.4	0.4*6.5 = 2.6	0.4+2.6= 3.0

The adjusted involvement rates (2.7 and 4.2) should be compared with the original rates (1.5 and 3.4). (The adjusted rates could be renormalized, but were not.)

LDVS Overview

Travel (in thousands)

	Vehicle Miles of Travel
Single Trailers	43,127,498
Multi Trailers	2,882,595
Other Vehicles	386,089,832
All Vehicles	432,100,028

Involvements

	Fatal Involvements	Non-Fatal Involvements
Single Trailers	1,054	13,568
Multi Trailers	60	725
Other Vehicles	8,950	314,721

Involvement Rates per 100 Million Vehicle Miles

	Fatal Involvement Rate	Non-Fatal Involvement Rate
Single Trailers	2.44	31.46
Multi Trailers	2.08	25.15
Other Vehicles	2.32	81.51
All Vehicles	2.33	76.14

Adjusted To Equalize Combination Truck Travel

	Fatal Involvement Rate	Non-Fatal Involvement Rate
Single Trailers	2.43	31.28
Multi Trailers	2.44	28.02
Combination Trucks	2.43	31.08

Table 1

LDVS Summary

	Rural Interstate	Rural Other	Urban Interstate	Urban Other	Total
VMT (1,000s)					
Single Trailers	21,134,101	11,728,579	8,799,123	1,465,695	43,127,498
Multi Trailers	1,656,791	644,073	535,119	46,612	2,882,595
Other Vehicles	94,513,560	122,744,915	120,600,268	48,231,089	386,089,832
Fatal Involvements					
Single Trailers	246	559	141	108	1,054
Multi Trailers	18	29	7	6	60
Other Vehicles	1,464	4,667	1,560	1,259	8,950
Fatal Involvement Rates					
Single Trailers	1.16	4.77	1.60	7.37	2.44
Multi Trailers	1.09	4.50	1.31	12.87	2.08
Other Vehicles	1.55	3.80	1.29	2.61	2.32
Non-Fatal Involvements					
Single Trailers	4,119	4,088	3,682	1,679	13,568
Multi Trailers	293	208	160	64	725
Other Vehicles	28,127	79,057	85,578	121,957	314,721
Non-Fatal Involvement Rates					
Single Trailers	19.48	34.86	41.85	114.55	31.46
Multi Trailers	17.68	32.29	29.90	137.30	25.15
Other Vehicles	29.76	64.41	70.96	252.86	81.51

Table 2

LDVS Rural Summary

	Interstate	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local	Total
VMT (1,000s)							
Single Trailers	21,134,101	8,981,885	2,554,887	165,256	283	26,268	32,862,680
Multi Trailers	1,656,791	526,166	97,306	15,442	0	5,159	2,300,864
Other Vehicles	94,513,560	86,314,185	33,663,851	2,635,720	6,471	124,688	217,258,475
Fatal Involvements							
Single Trailers	246	426	127	6	0	0	805
Multi Trailers	18	27	1	1	0	0	47
Other Vehicles	1,464	3,193	1,339	123	0	12	6,131
Fatal Involvement Rates							
Single Trailers	1.16	4.74	4.97	3.63	0.00	0.00	2.45
Multi Trailers	1.09	5.13	1.03	6.48	-	0.00	2.04
Other Vehicles	1.55	3.70	3.98	4.67	0.00	9.62	2.82
Non-Fatal Involvements							
Single Trailers	4,119	2,922	1,075	86	1	4	8,207
Multi Trailers	293	153	44	11	0	0	501
Other Vehicles	28,127	52,109	24,627	2240	7	74	107,184
Non-Fatal Involvement Rates							
Single Trailers	19.49	32.53	42.08	52.04	353.36	15.23	24.97
Multi Trailers	17.68	29.08	45.22	71.23	-	0.00	21.77
Other Vehicles	29.76	60.37	73.16	84.99	108.17	59.35	49.33

Table 3

LDVS Urban Summary

	Interstate	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local	Total
VMT (1,000s)							
Single Trailers	8,799,123	490,398	938,908	31,714	160	4,515	102,648,818
Multi Trailers	535,119	19,271	26,007	766	0	568	581,731
Other Vehicles	120,600,268	16,232,592	30,998,060	900,369	11,192	88,876	168,831,357
Fatal Involvements							
Single Trailers	141	19	86	2	0	1	249
Multi Trailers	7	2	4	0	0	0	13
Other Vehicles	1,560	310	917	26	1	5	2,819
Fatal Involvement Rates							
Single Trailers	1.60	3.87	9.16	6.31	0.00	22.15	2.43
Multi Trailers	1.31	10.38	15.38	0.00	-	0.00	5.63
Other Vehicles	1.29	1.91	2.96	2.89	8.93	5.63	1.67
Non-Fatal Involvements							
Single Trailers	3,682	304	1,344	27	0	4	5,361
Multi Trailers	160	23	41	0	0	0	224
Other Vehicles	85,578	16,195	102,586	3,049	14	113	207,535
Non-Fatal Involvement Rates							
Single Trailers	41.85	61.99	143.15	85.14	0.00	88.59	52.23
Multi Trailers	29.90	119.35	157.65	0.00	-	0.00	38.51
Other Vehicles	70.96	99.77	330.94	338.64	125.09	127.14	122.92

Table 4

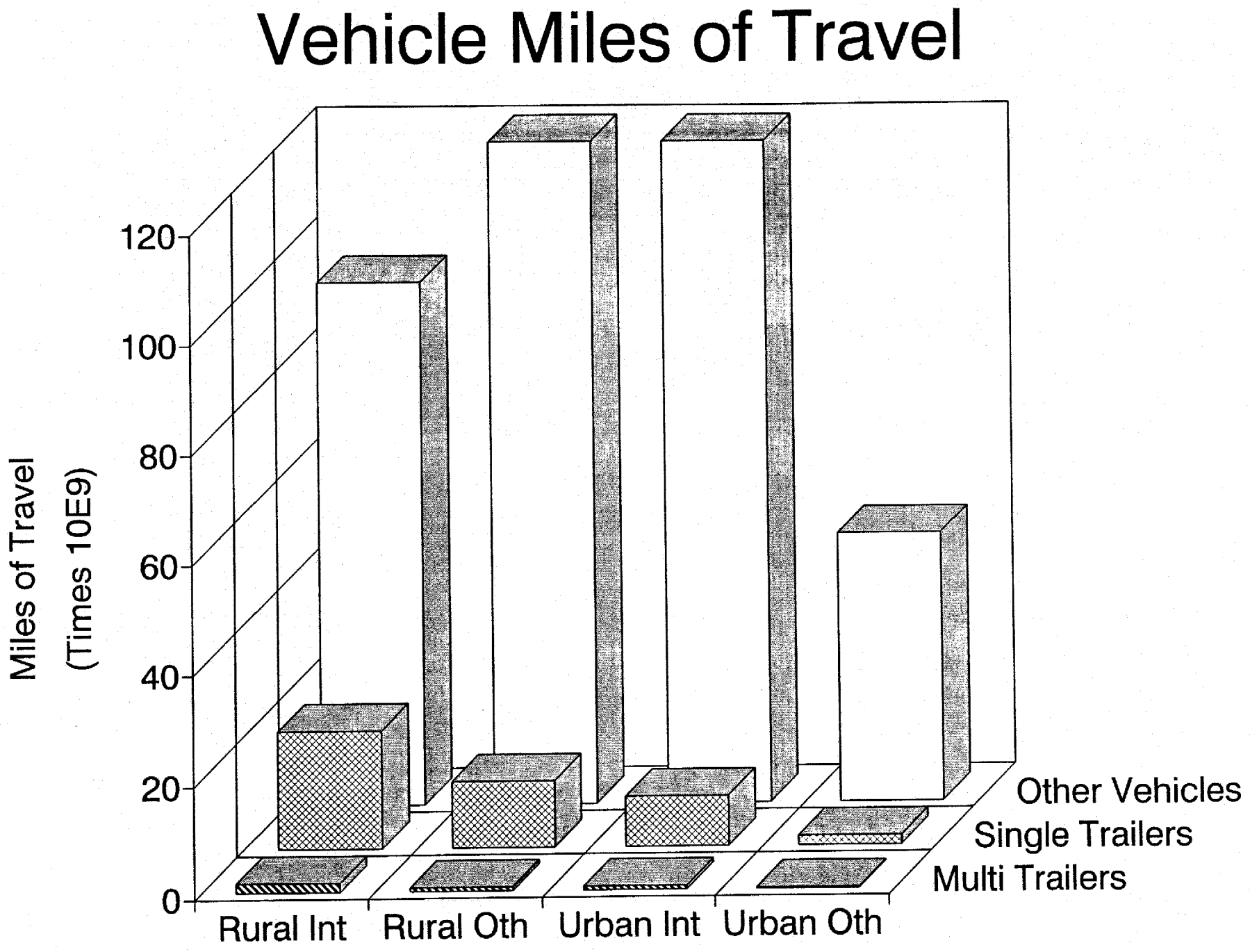
Vehicle Miles of Travel
Miles of Travel
(Times 10E9)
120
100
80
60
40
20
0
Rural Int
Rural Oth
Urban Int
Urban Oth
Other Vehicles
Single Trailers
Multi Trailers

Figure 1

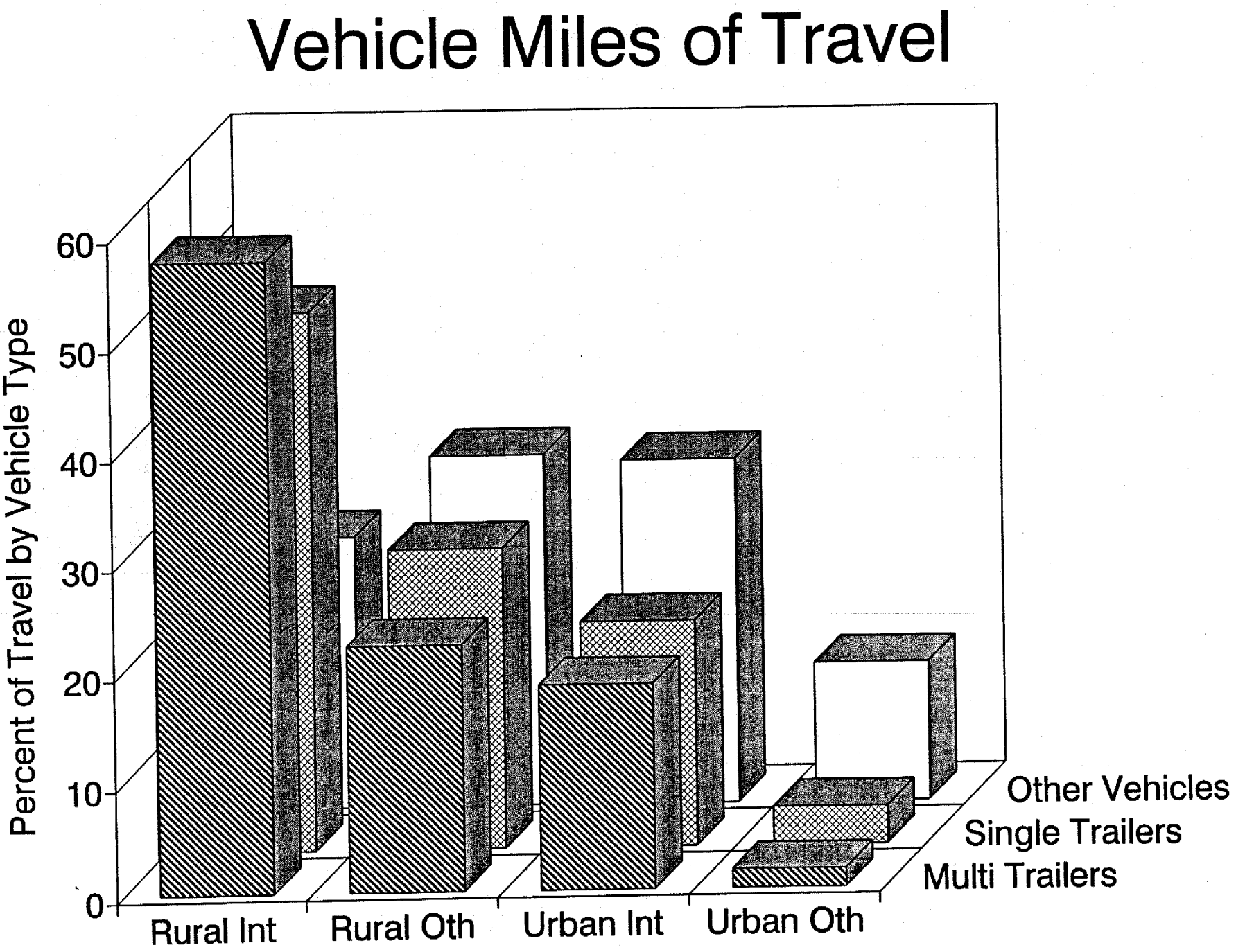
Vehicle Miles of Travel
Percent of Travel by Vehicle Type
60
50
40
30
20
10
0
Rural Int
Rural Oth
Urban Int
Urban Oth
Other Vehicles
Single Trailers
Multi Trailers

Figure 2

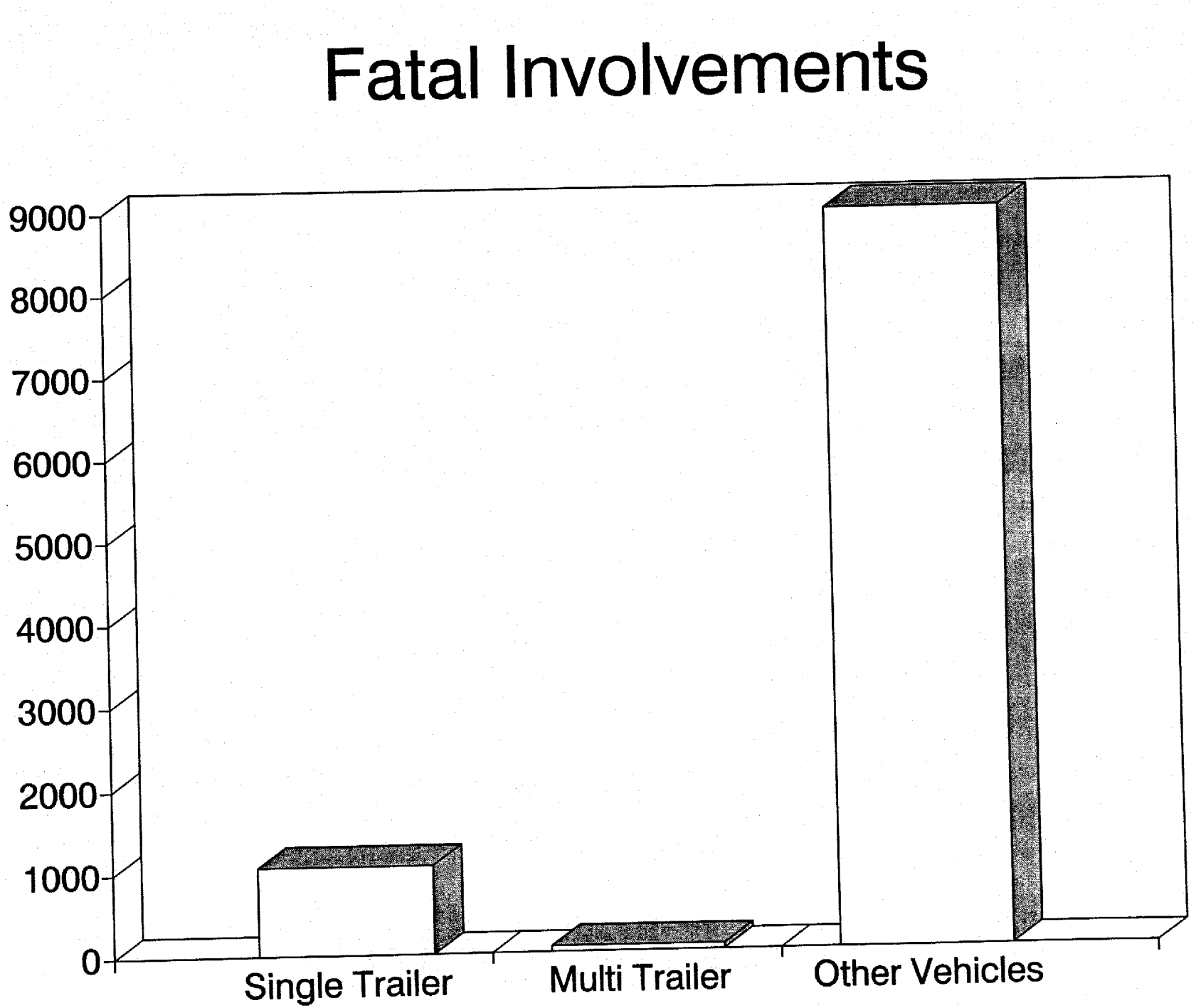
Fatal Involvements
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Single Trailer
Multi Trailer
Other Vehicles

Figure 3

Fatal Involvements

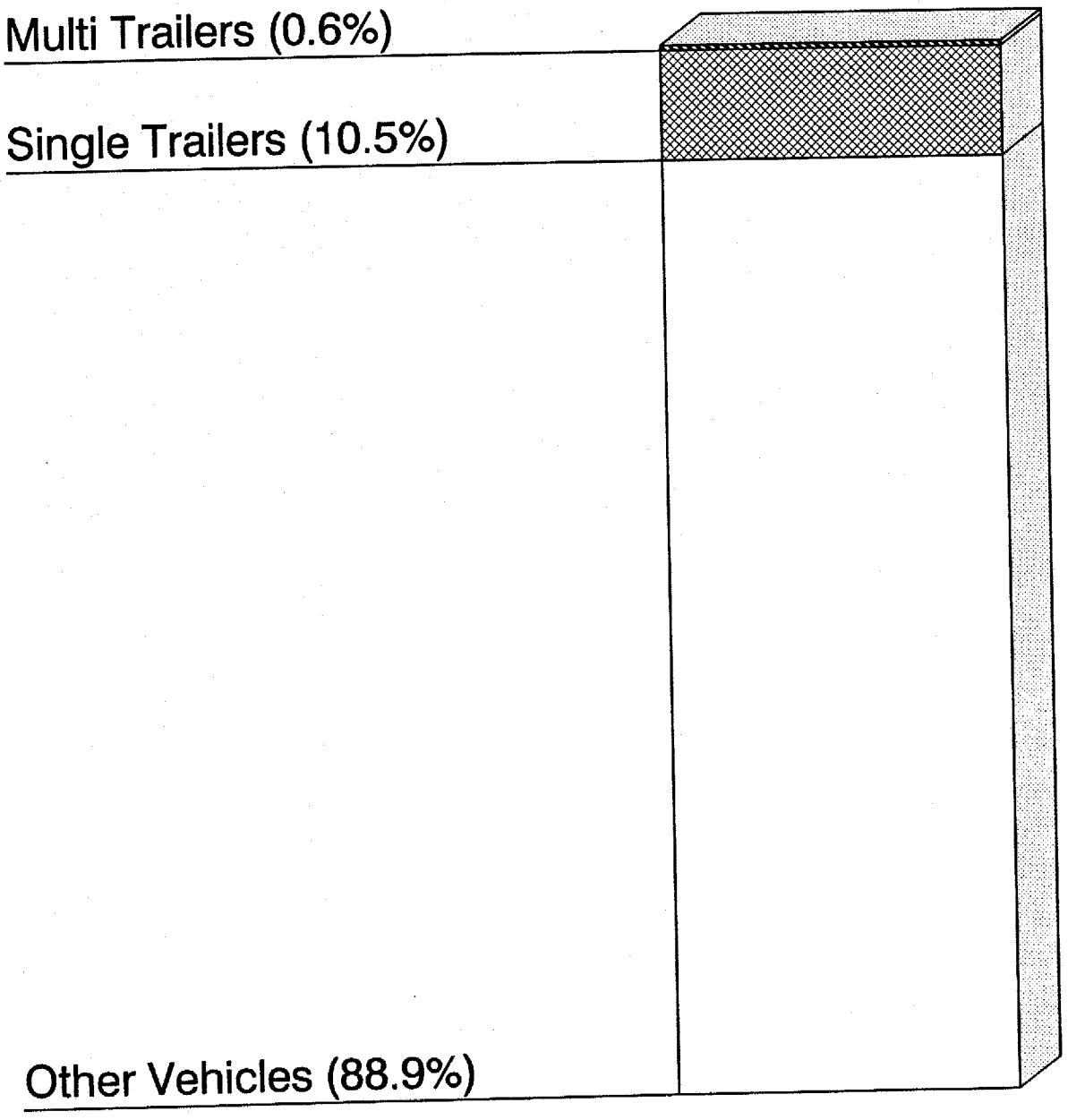

Figure 4

Fatal Involvements by Functional Class

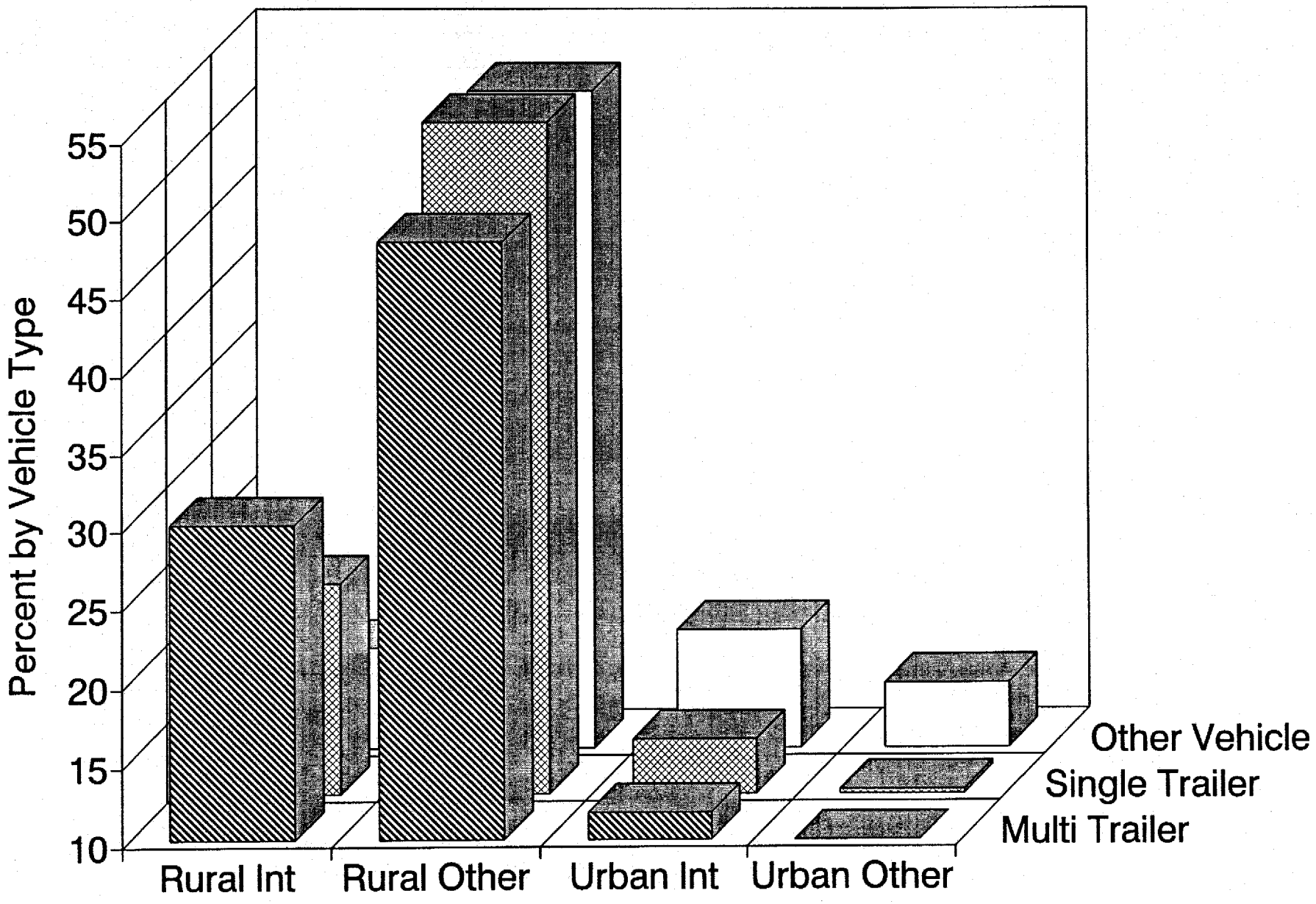

Figure 5

Fatal Involvement Rates

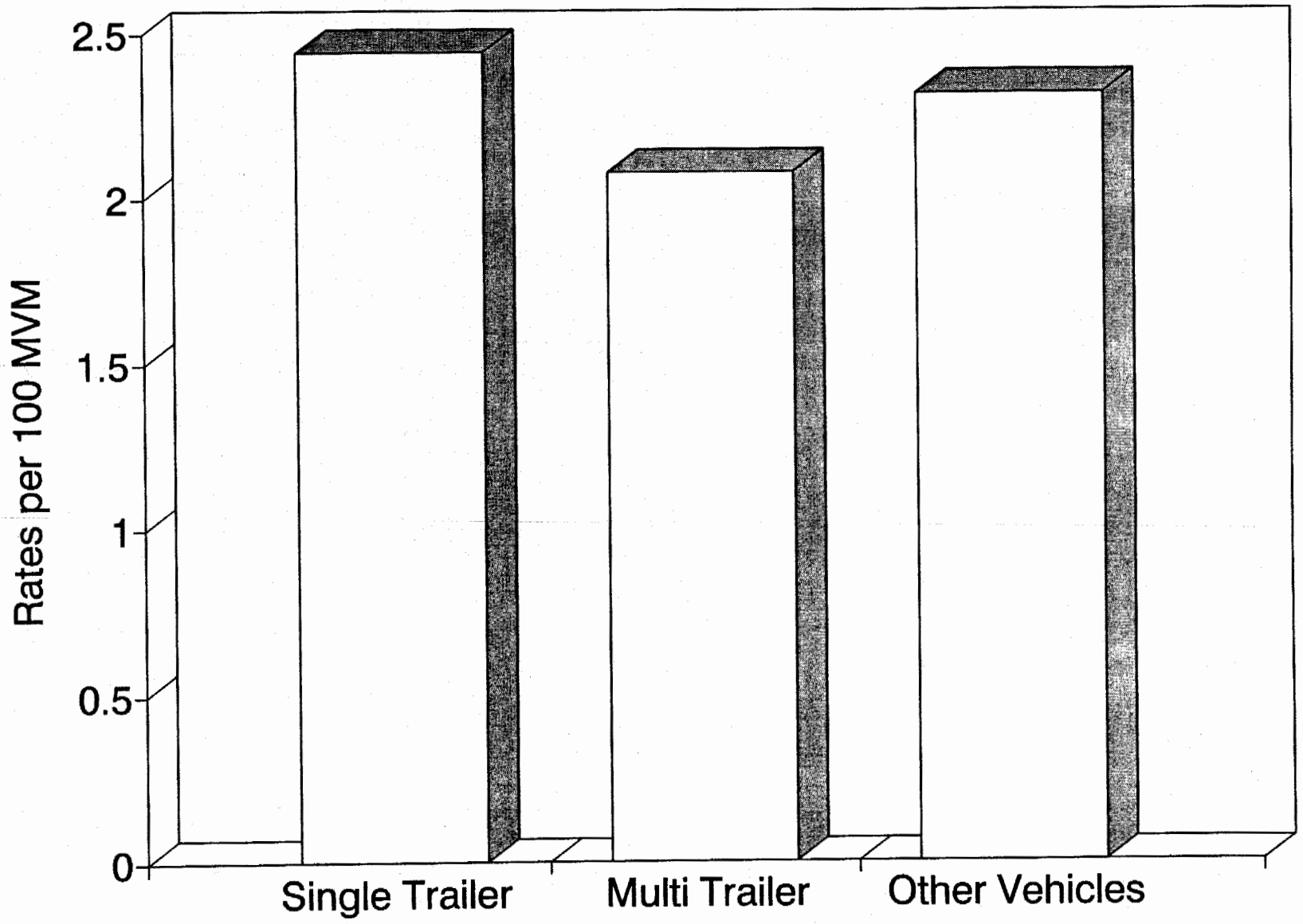

Figure 6

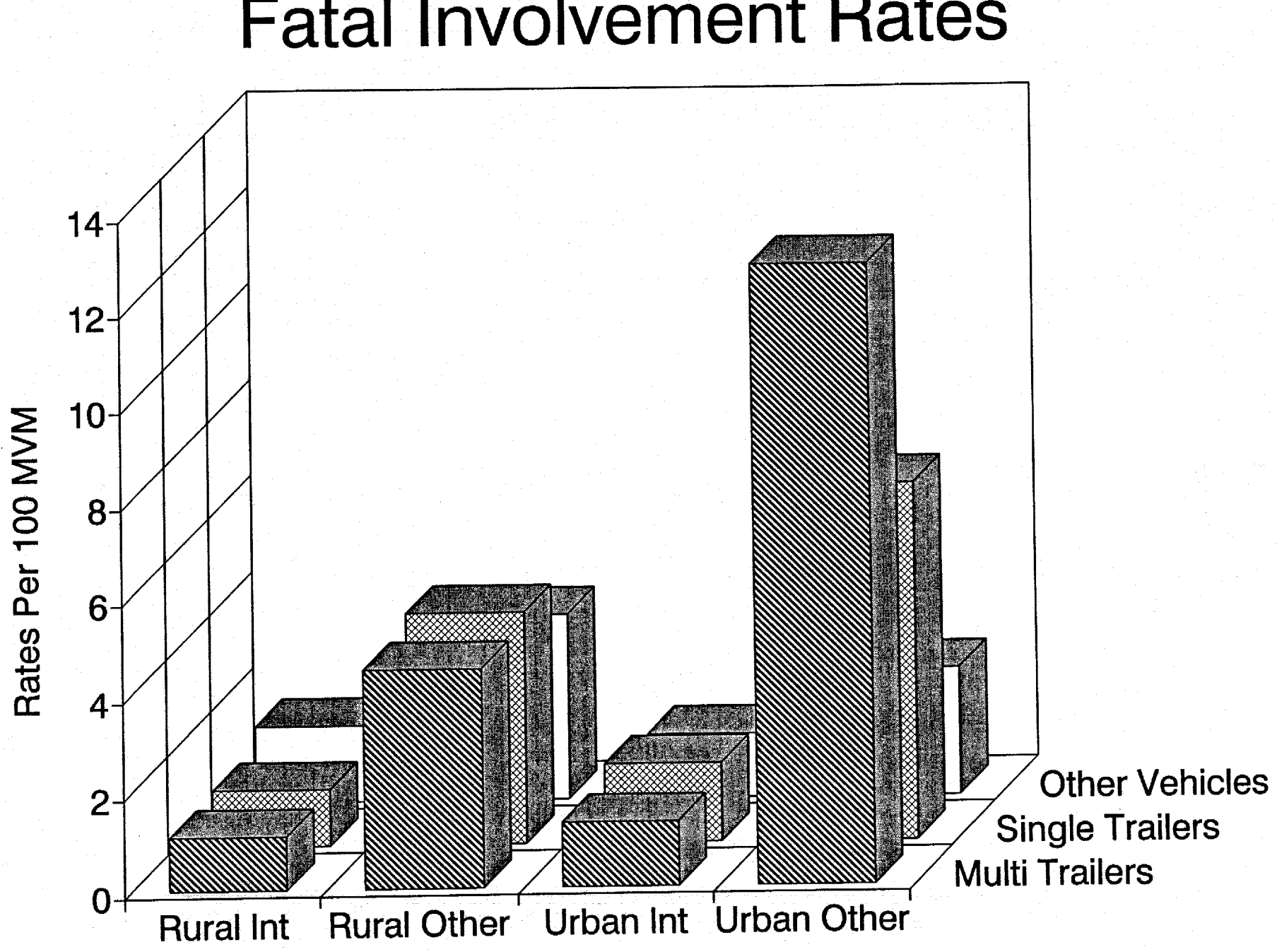
Fatal Involvement Rates
Rates Per 100 MVM
14
12
10
8
6
4
2
0
Rural Int
Rural Other
Urban Int
Urban Other
Other Vehicles
Single Trailers
Multi Trailers

Figure 7

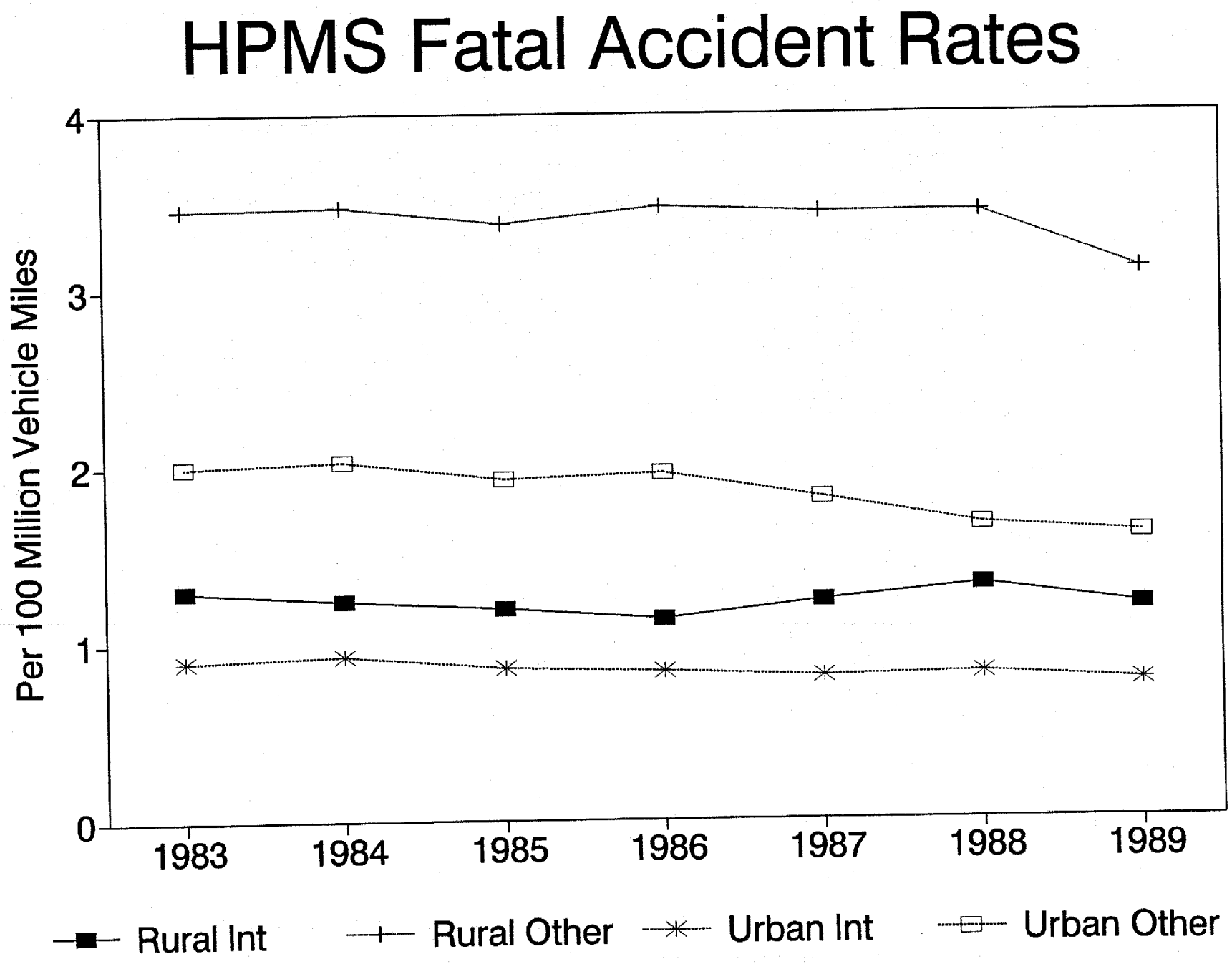
HPMS Fatal Accident Rates
Per 100 Million Vehicle Miles
4
3
2
1
0
1983
1984
1985
1986
1987
1988
1989
Rural Int
Rural Other
Urban Int
Urban Other

Figure 8

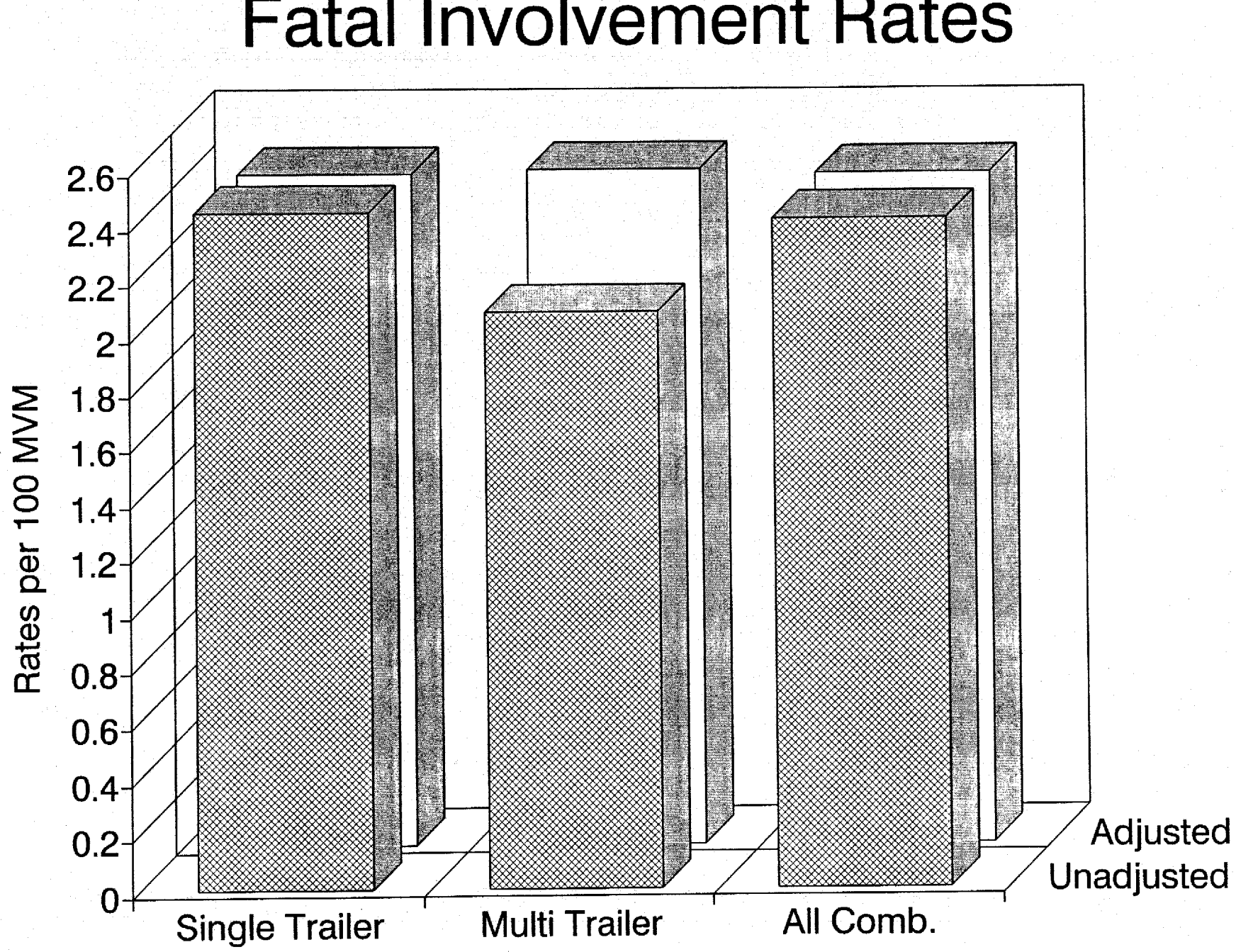
Fatal Involvement Rates
Rates per 100 MVM
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Single Trailer
Multi Trailer
All Comb.
Adjusted
Unadjusted

Figure 9

Normalized Fatal Involvement Rates

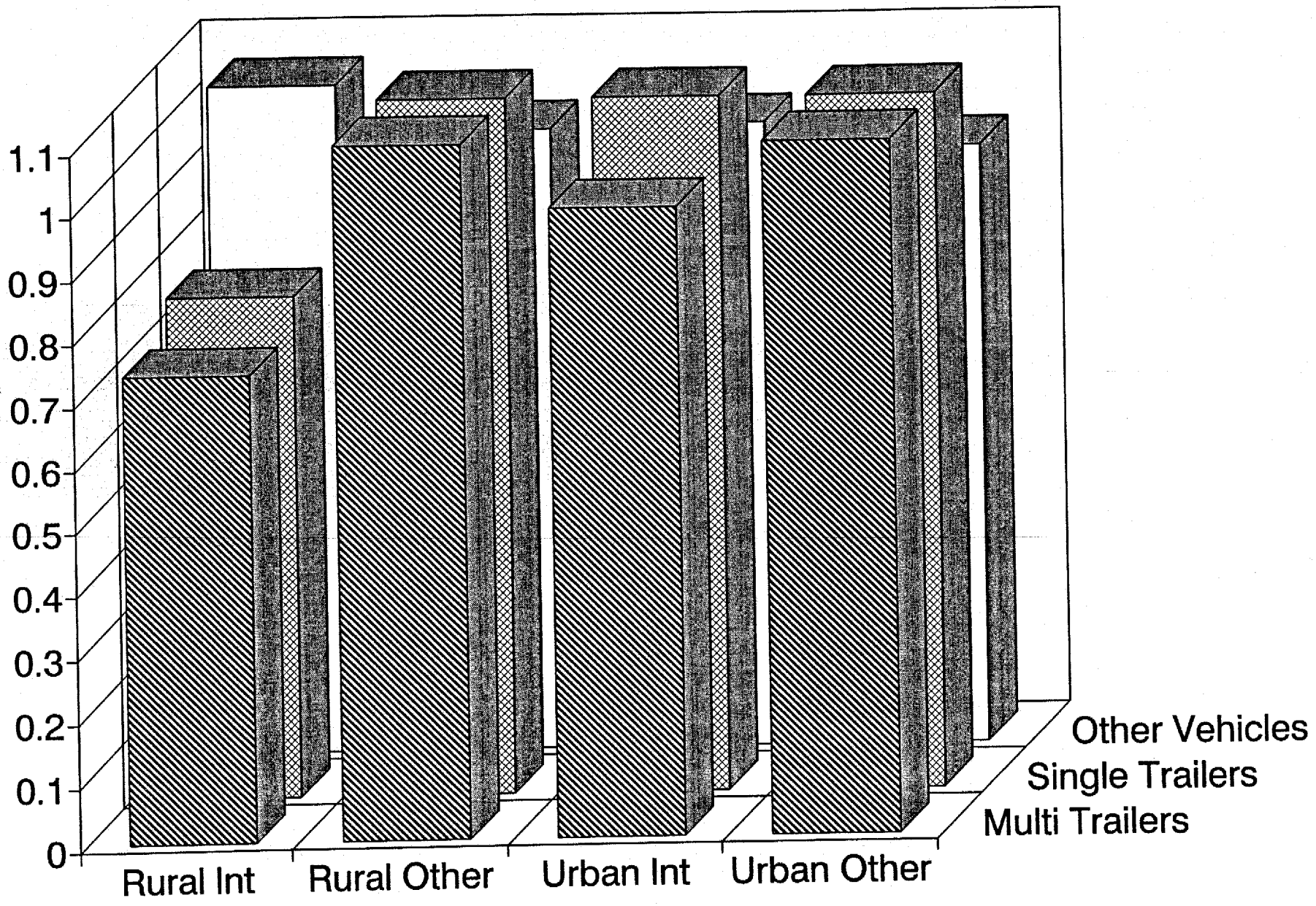

Figure 10

Rural Fatal Involvement Rates

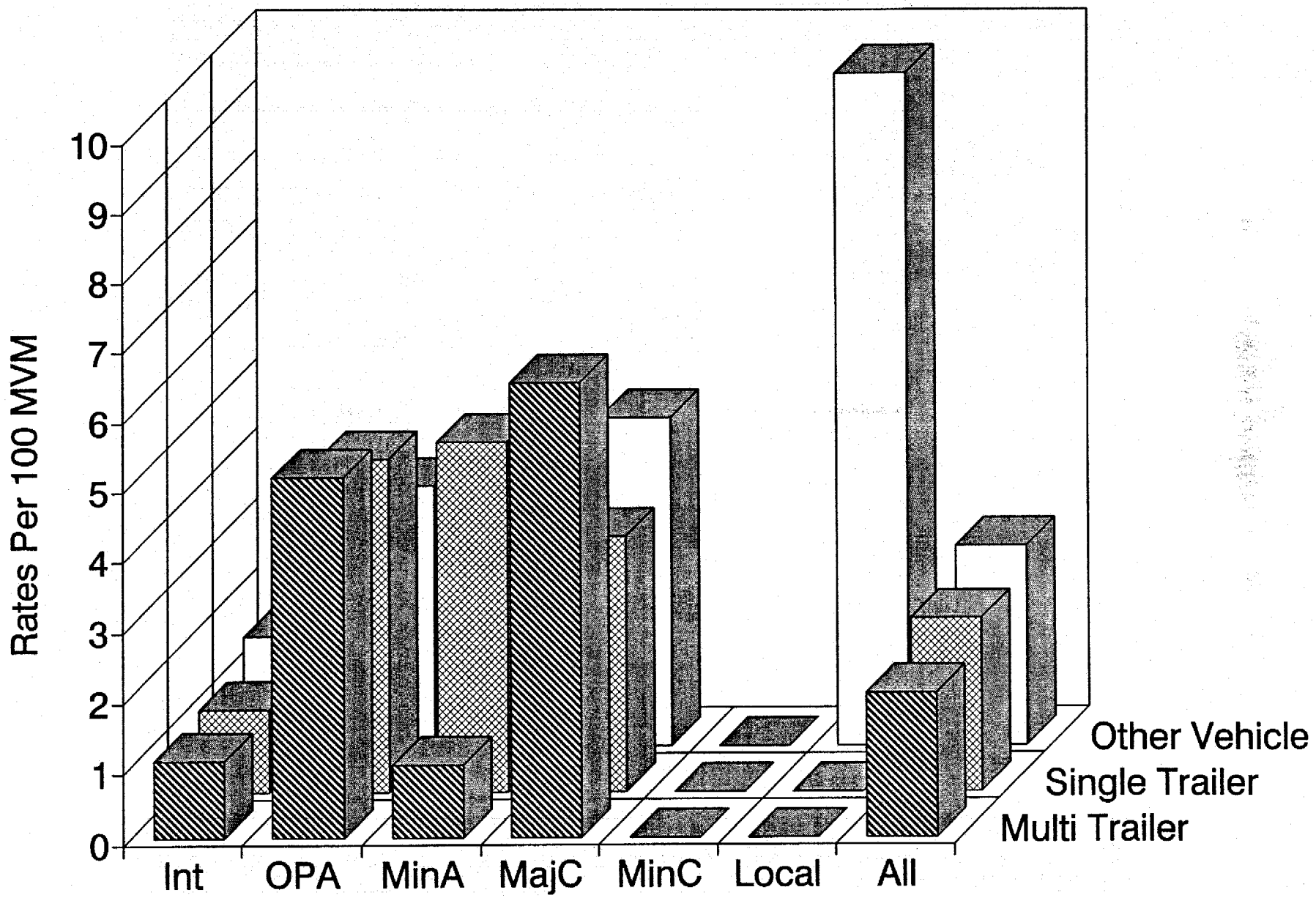

Figure 11

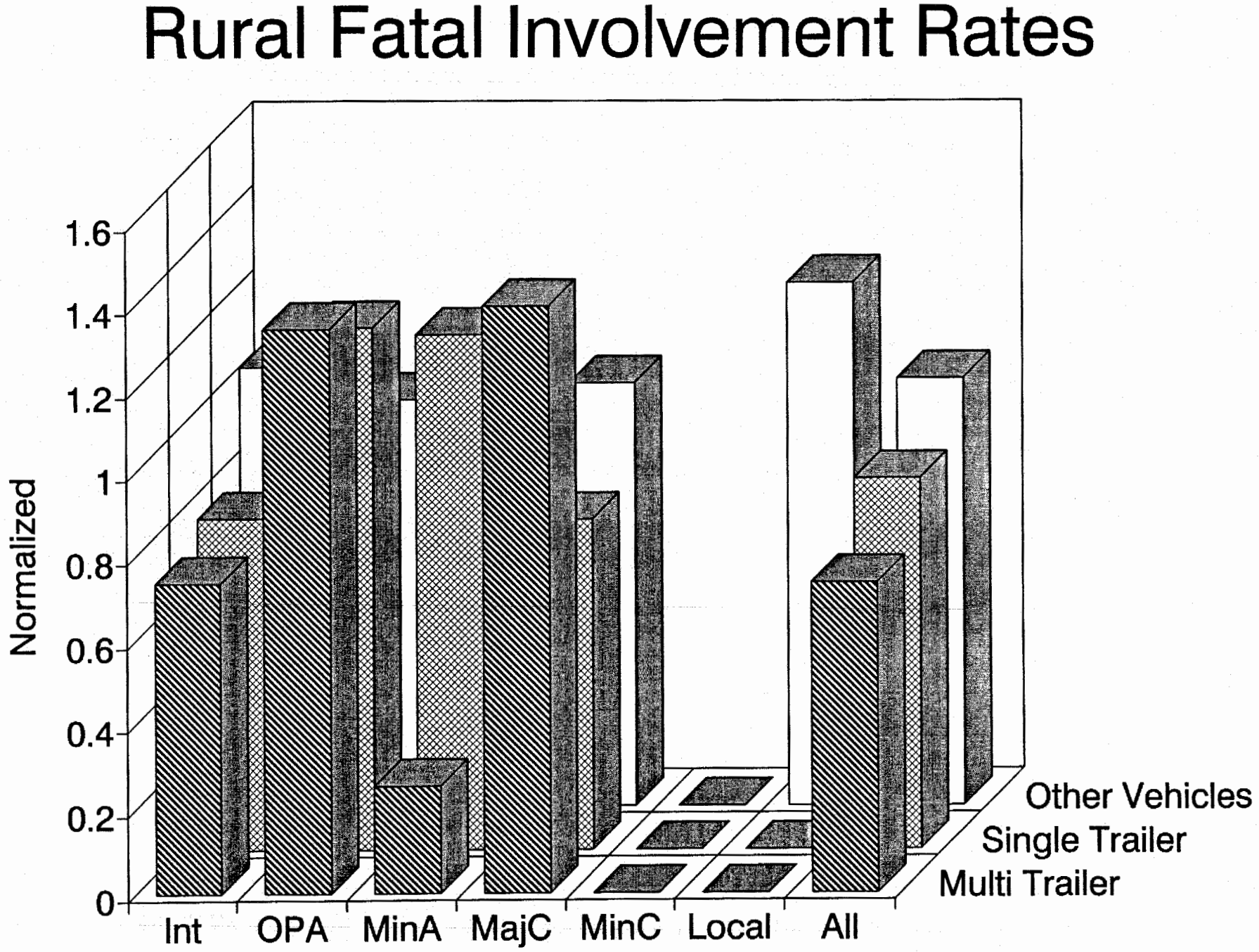
Rural Fatal Involvement Rates
Normalized
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Int
OPA
MinA
MajC
MinC
Local
All
Other Vehicles
Single Trailer
Multi Trailer

Figure 12

Urban Fatal Involvement Rates

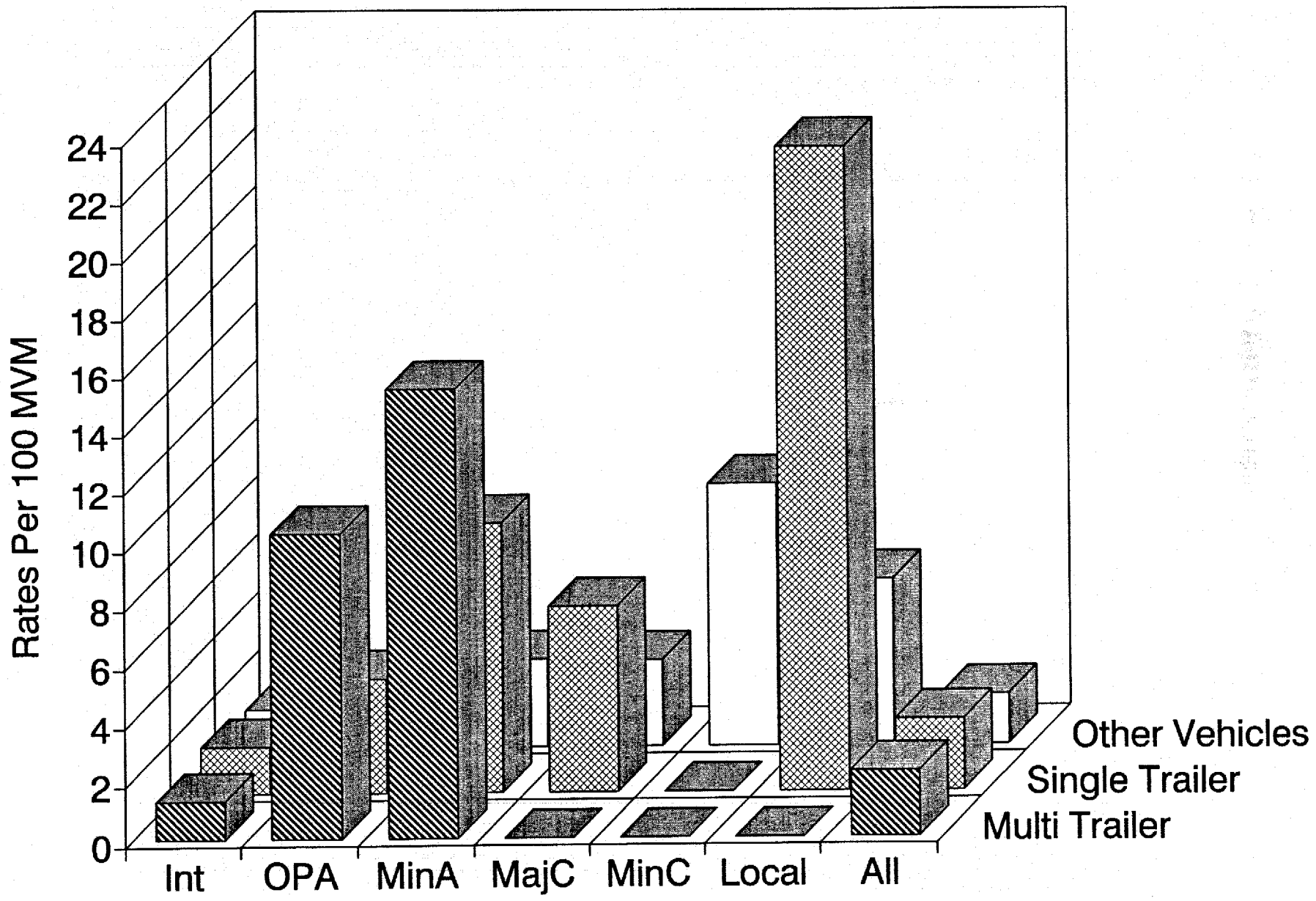

Figure 13

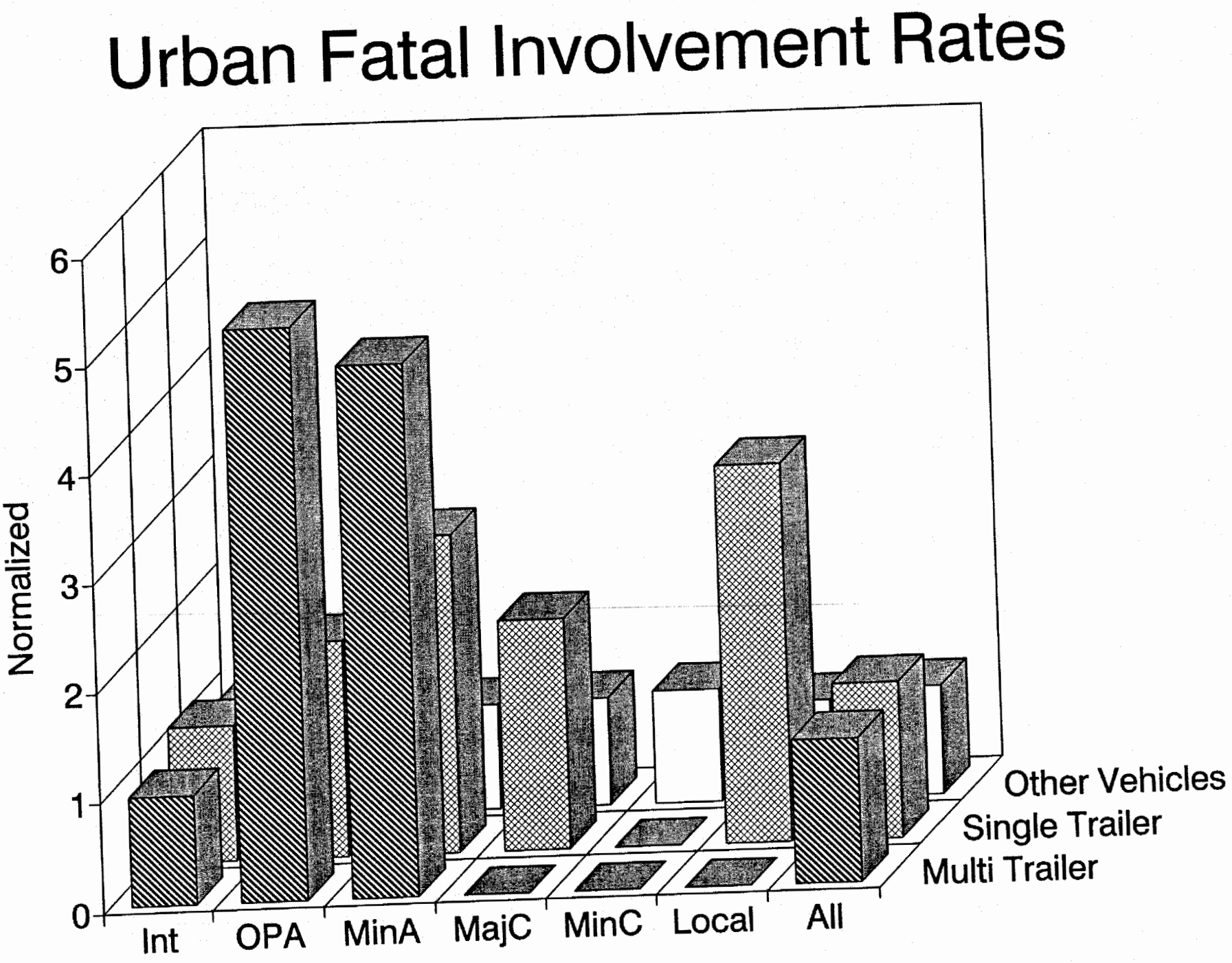
Urban Fatal Involvement Rates
Normalized
6
5
4
3
2
1
0
Int
OPA
MinA
MajC
MinC
Local
All
Other Vehicles
Single Trailer
Multi Trailer

Figure 14

Non-Fatal Involvements

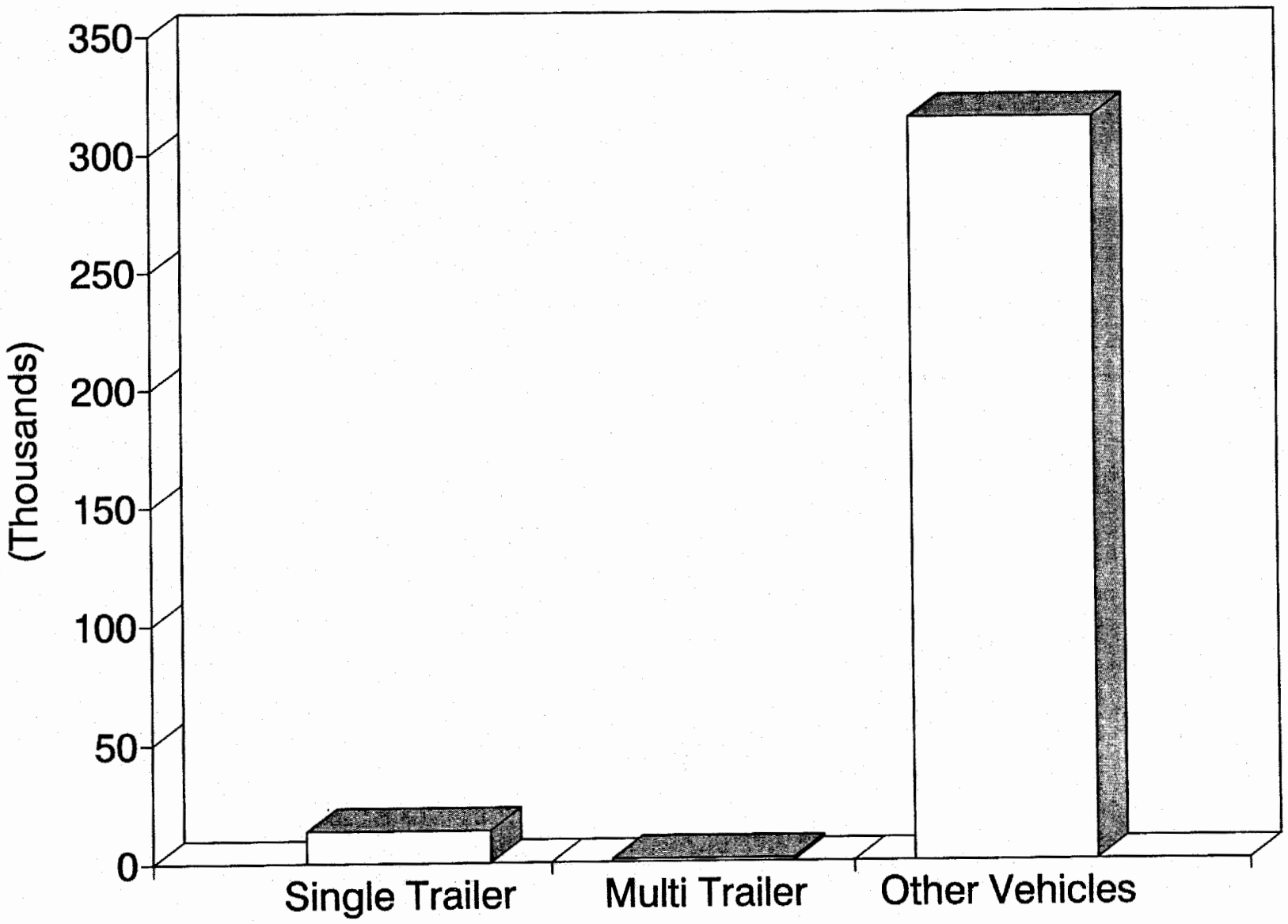

Figure 15

Non-Fatal Involvements

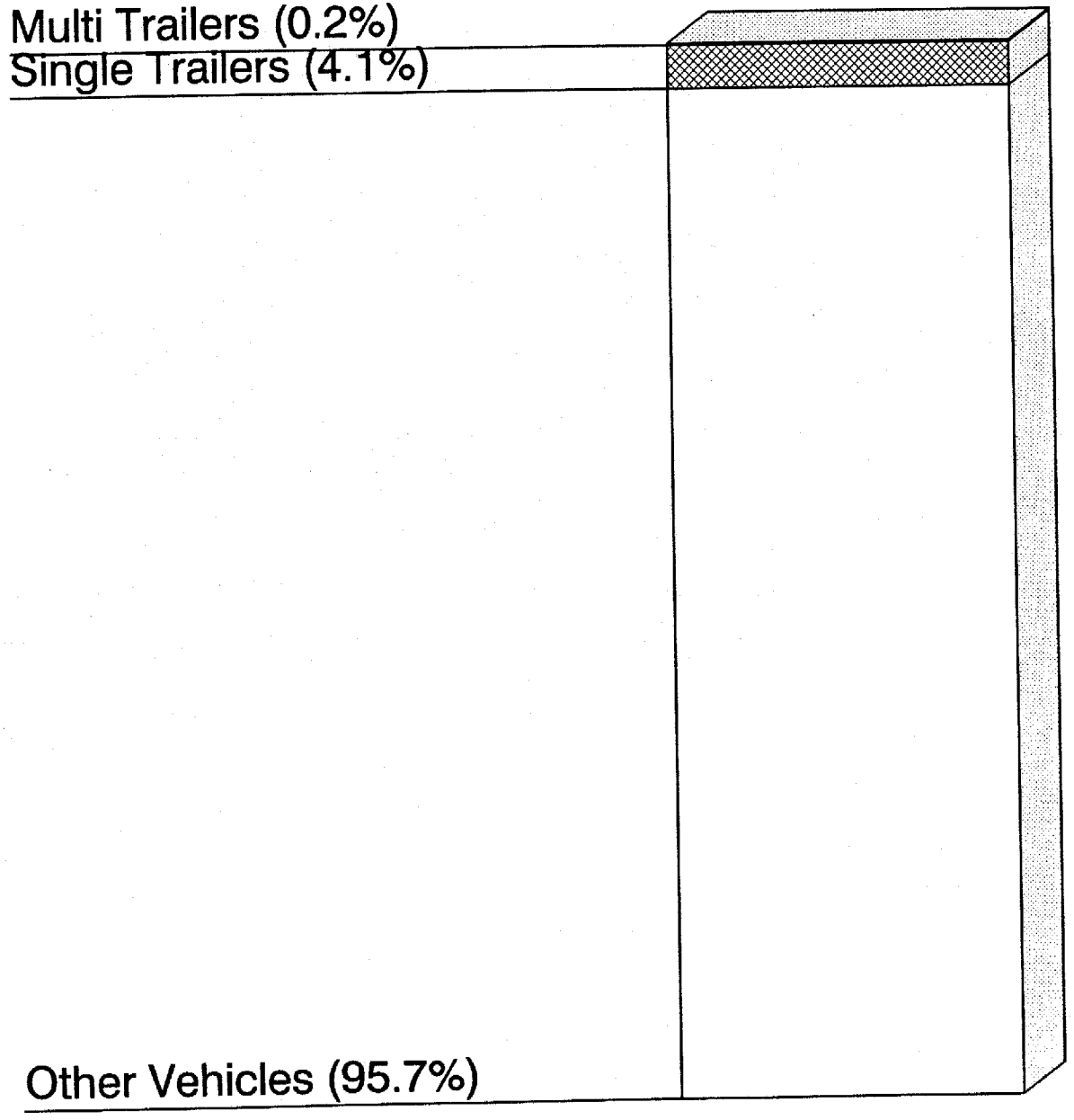

Figure 16

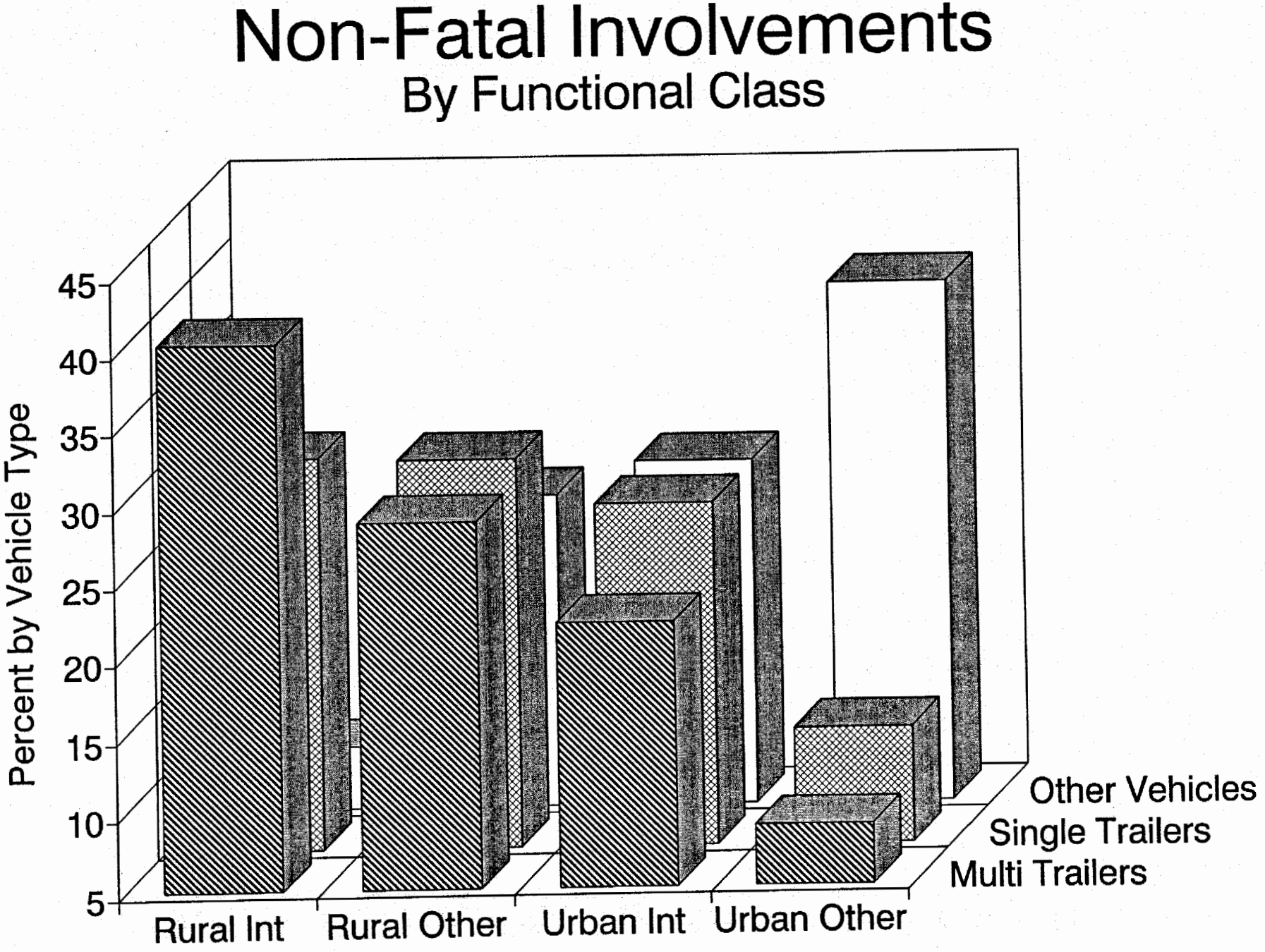
Non-Fatal Involvements
By Functional Class
Percent by Vehicle Type
45
40
35
30
25
20
15
10
5
Rural Int
Rural Other
Urban Int
Urban Other
Other Vehicles
Single Trailers
Multi Trailers

Figure 17

Non-Fatal Involvement Rates

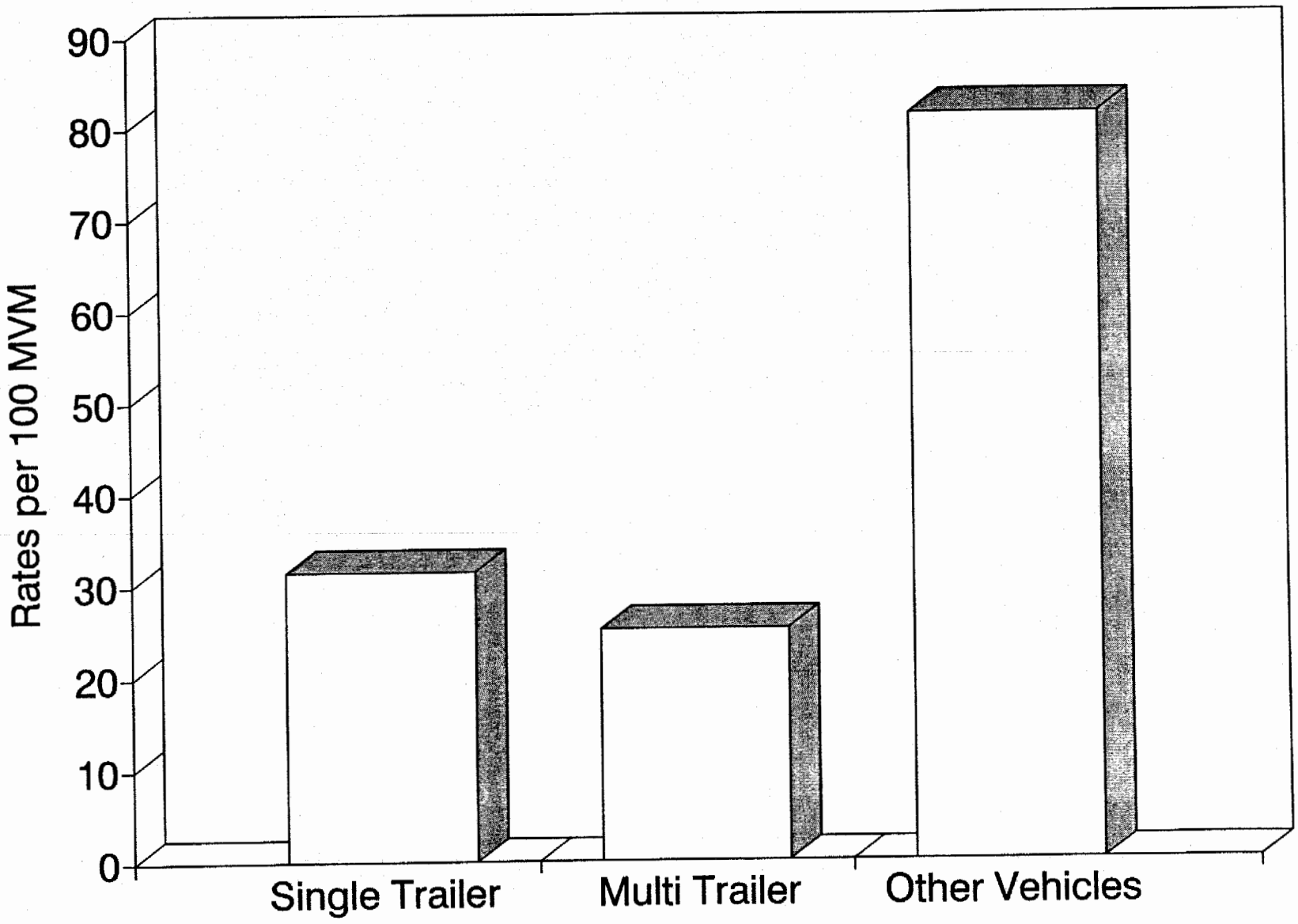

Figure 18

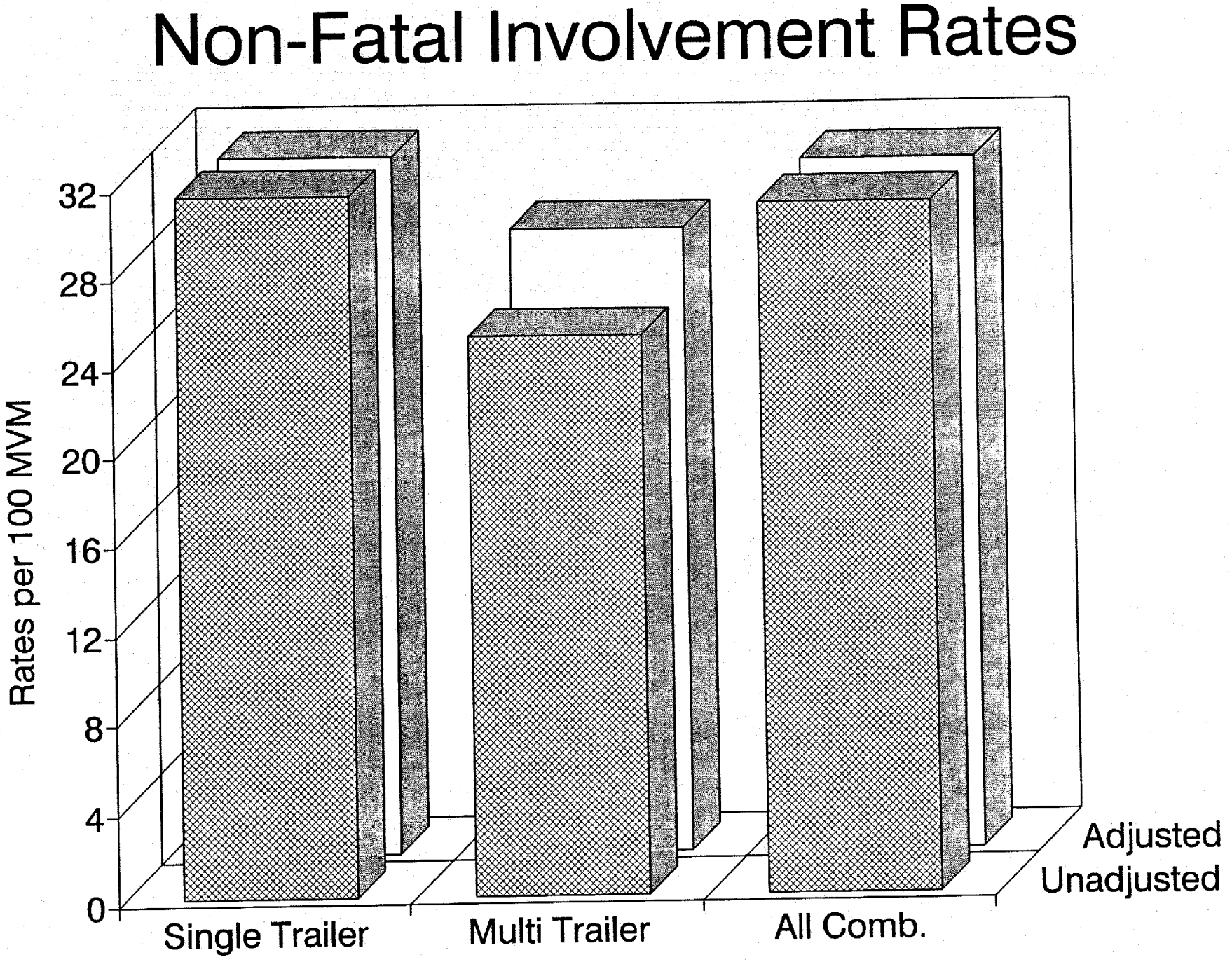
Non-Fatal Involvement Rates
Rates per 100 MVM
32
28
24
20
16
12
8
4
0
Single Trailer
Multi Trailer
All Comb.
Adjusted
Unadjusted

Figure 19

Normalized Non-Fatal Involvement Rates

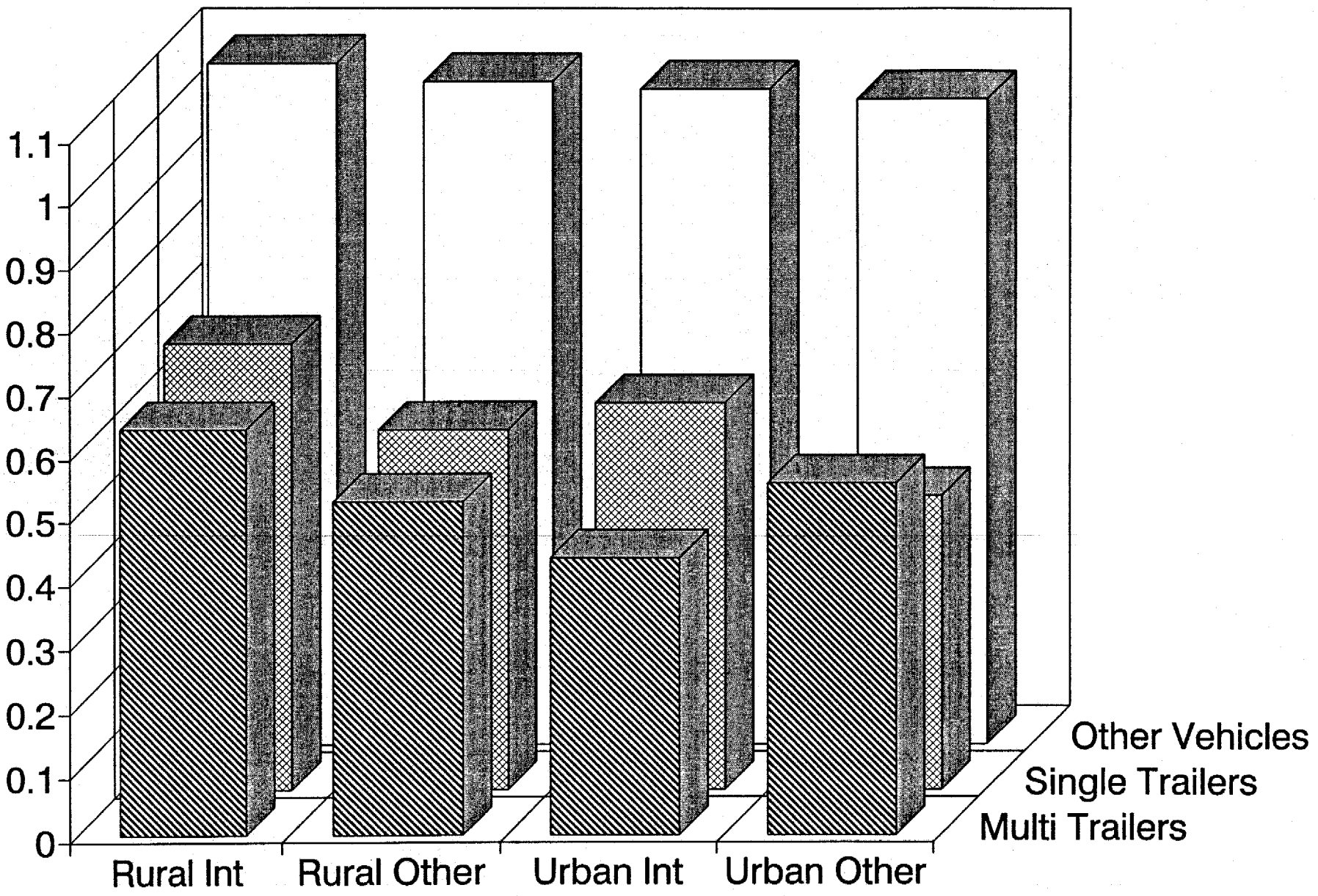

Figure 20

Non-Fatal Involvement Rates

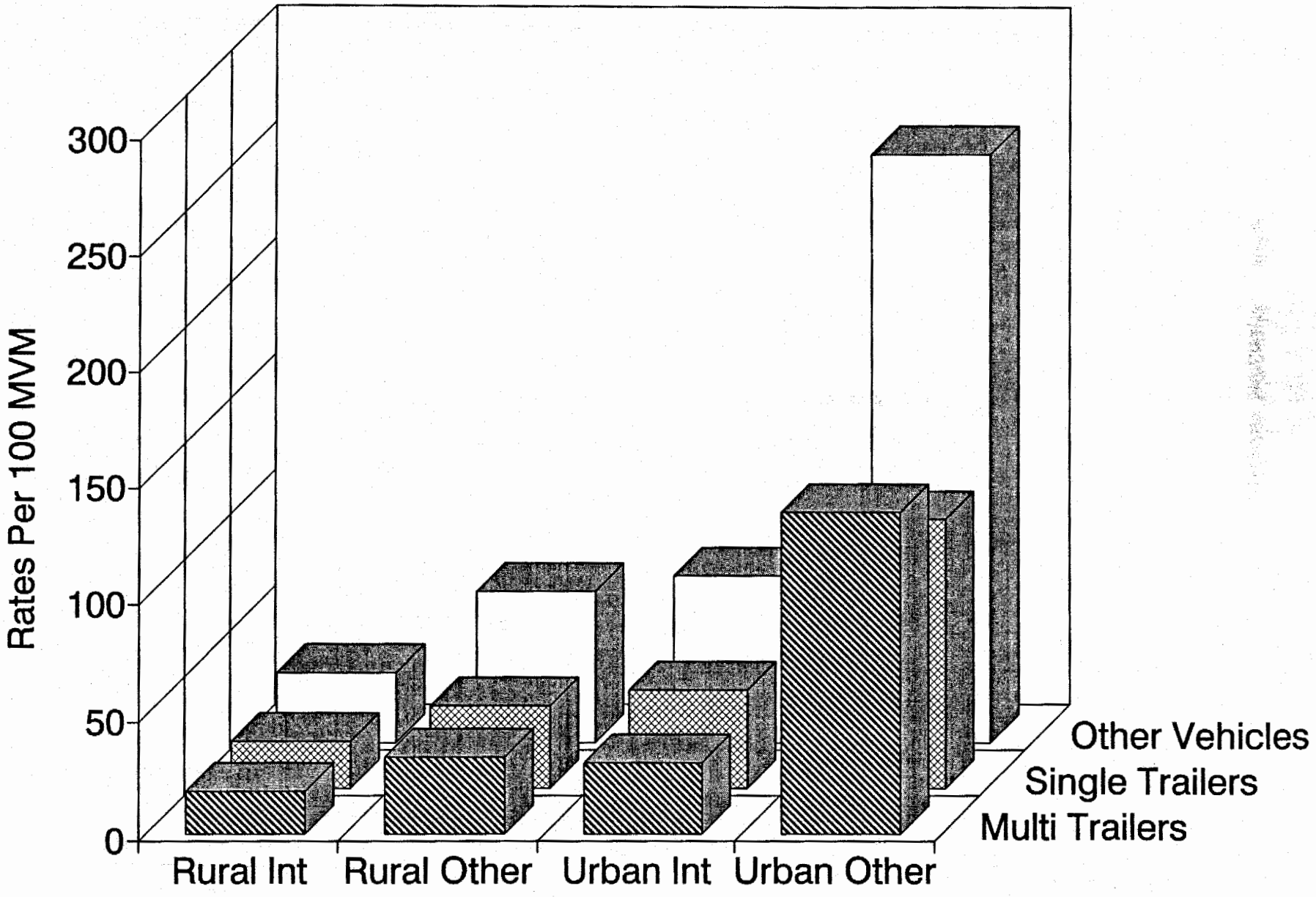

Figure 21

HPMS Non-Fatal Accident Rates

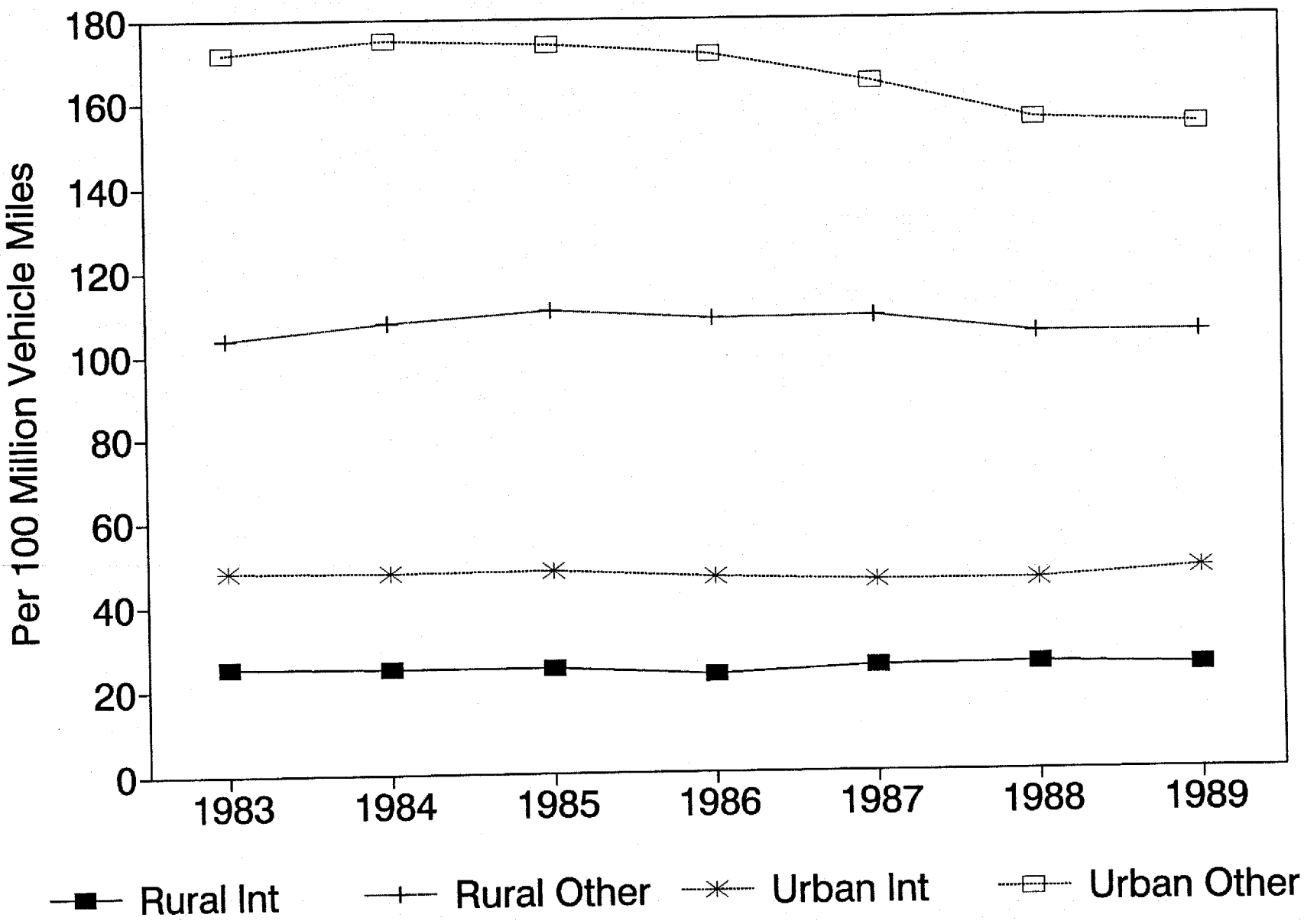

Figure 22

Rural Non-Fatal Involvement Rates

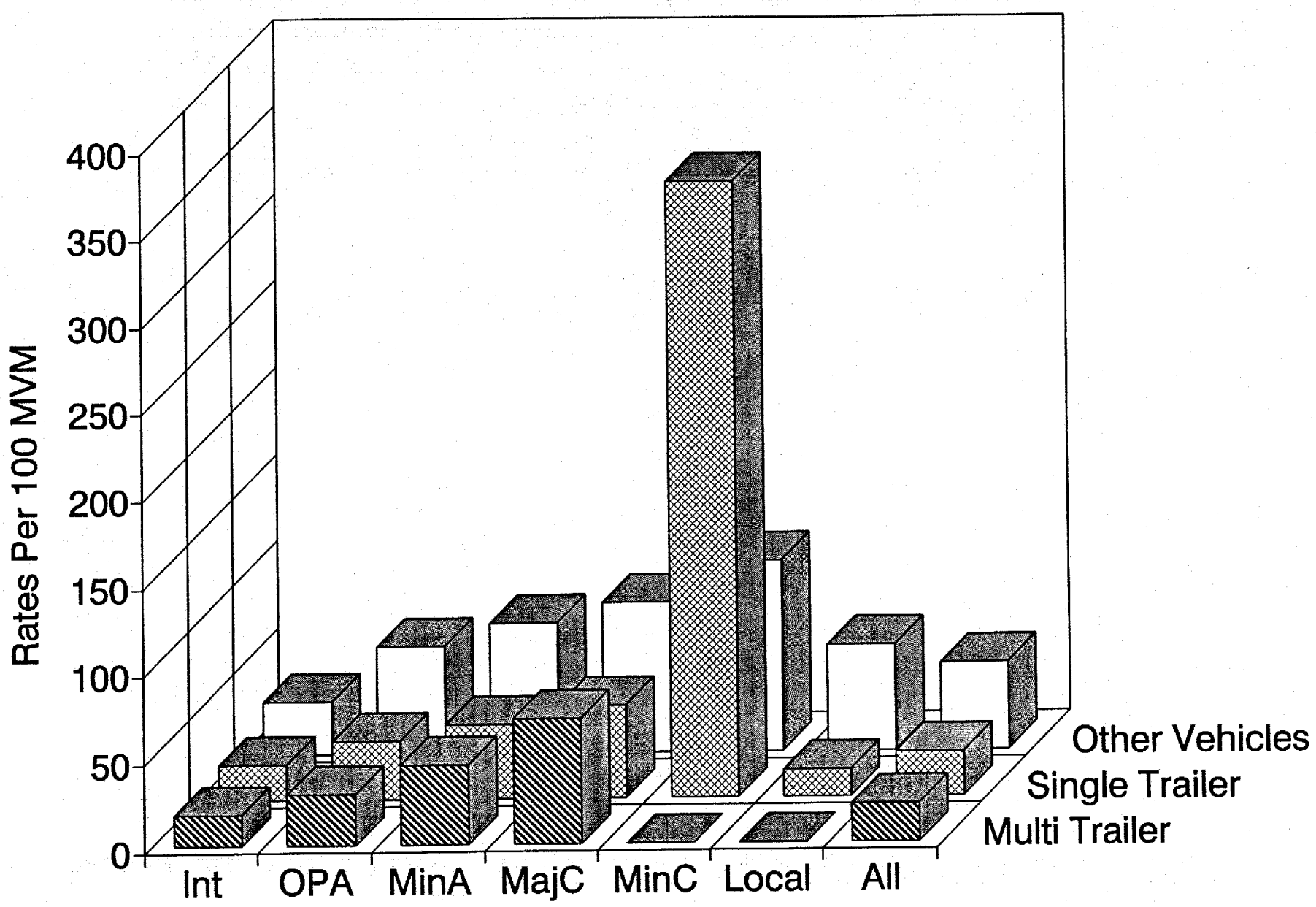

Figure 23

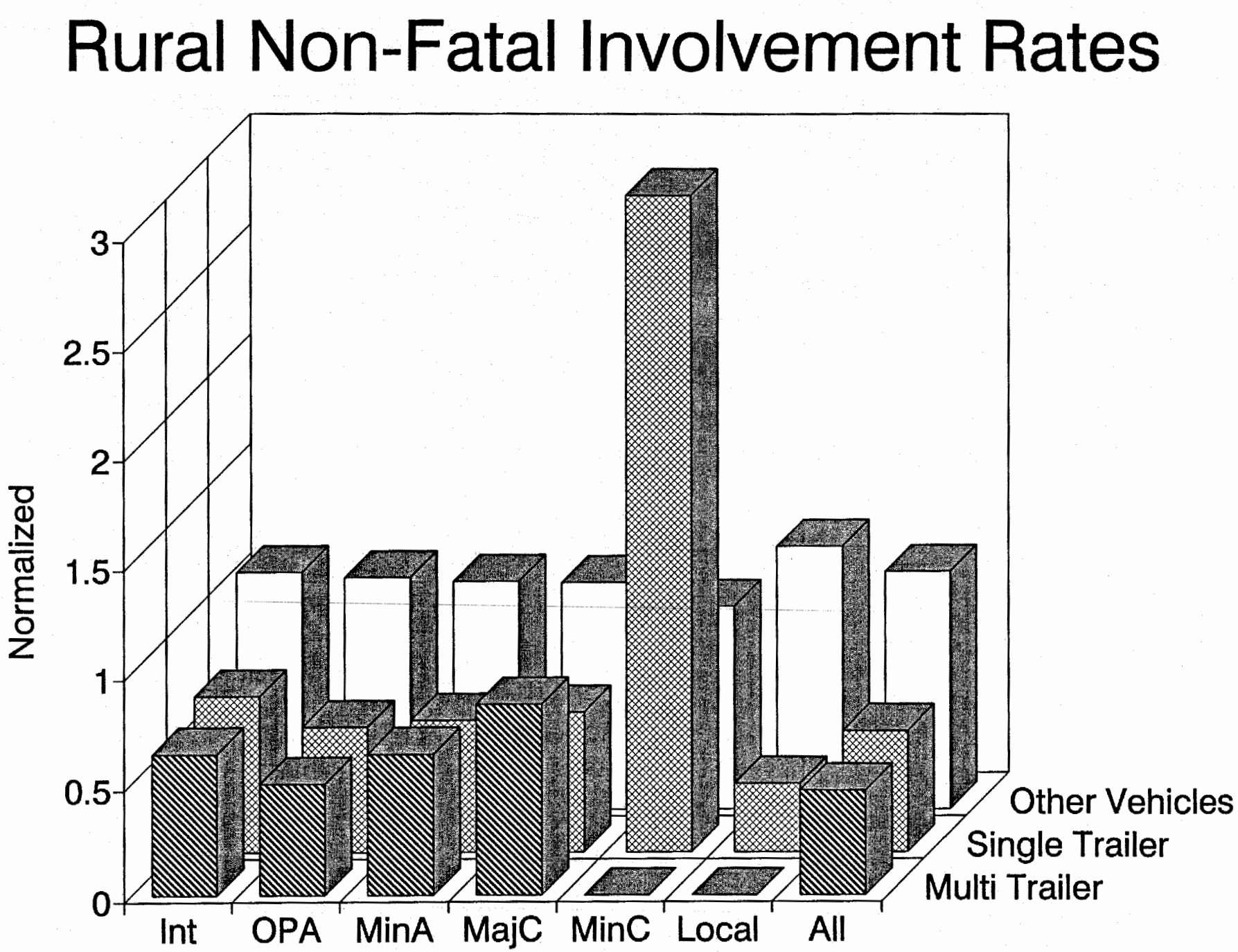
Rural Non-Fatal Involvement Rates
Normalized
3
2.5
2
1.5
1
0.5
0
Int
OPA
MinA
MajC
MinC
Local
All
Other Vehicles
Single Trailer
Multi Trailer

Figure 24

Urban Non-Fatal Involvement Rates

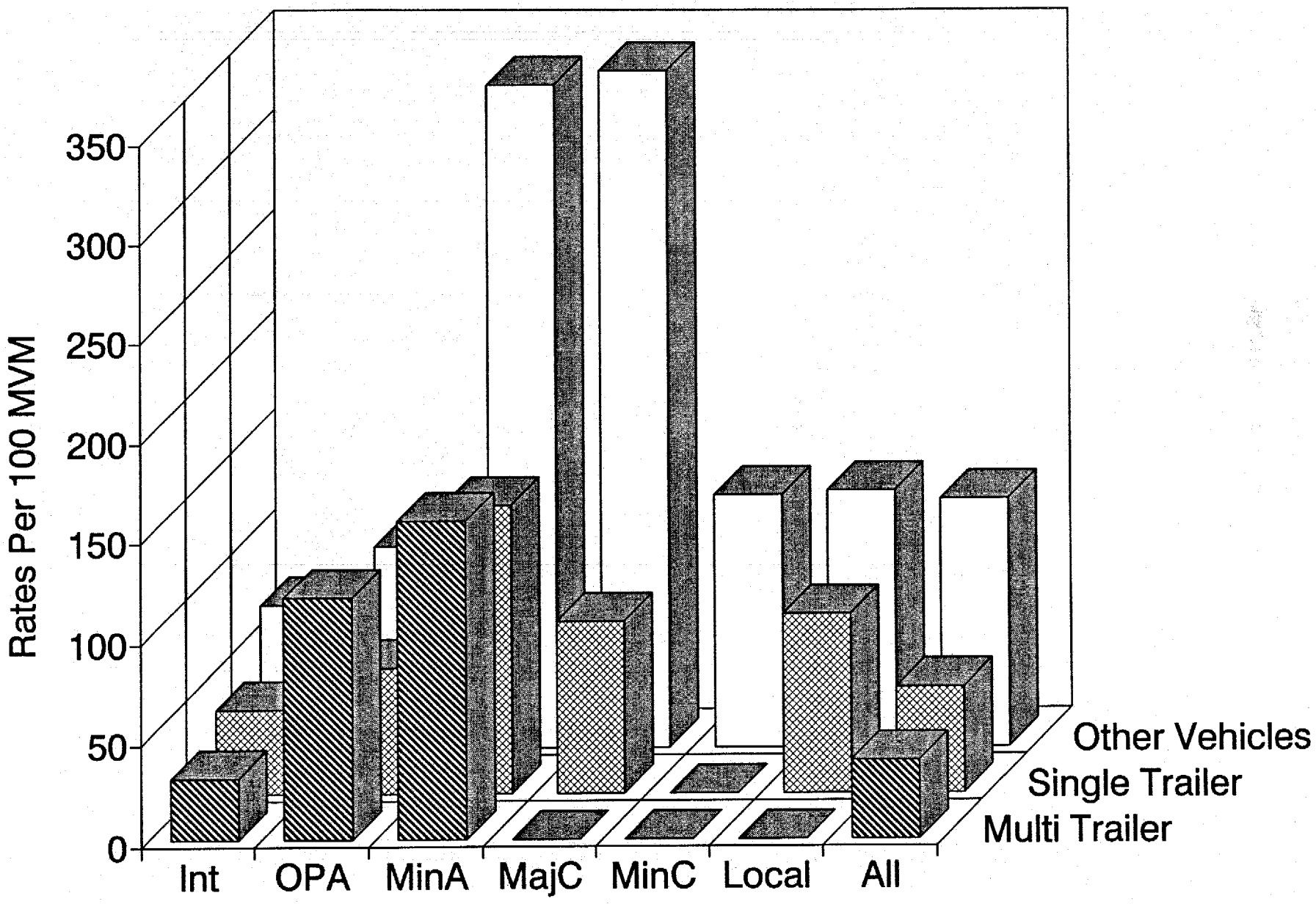

Figure 25

Urban Non-Fatal Involvement Rates

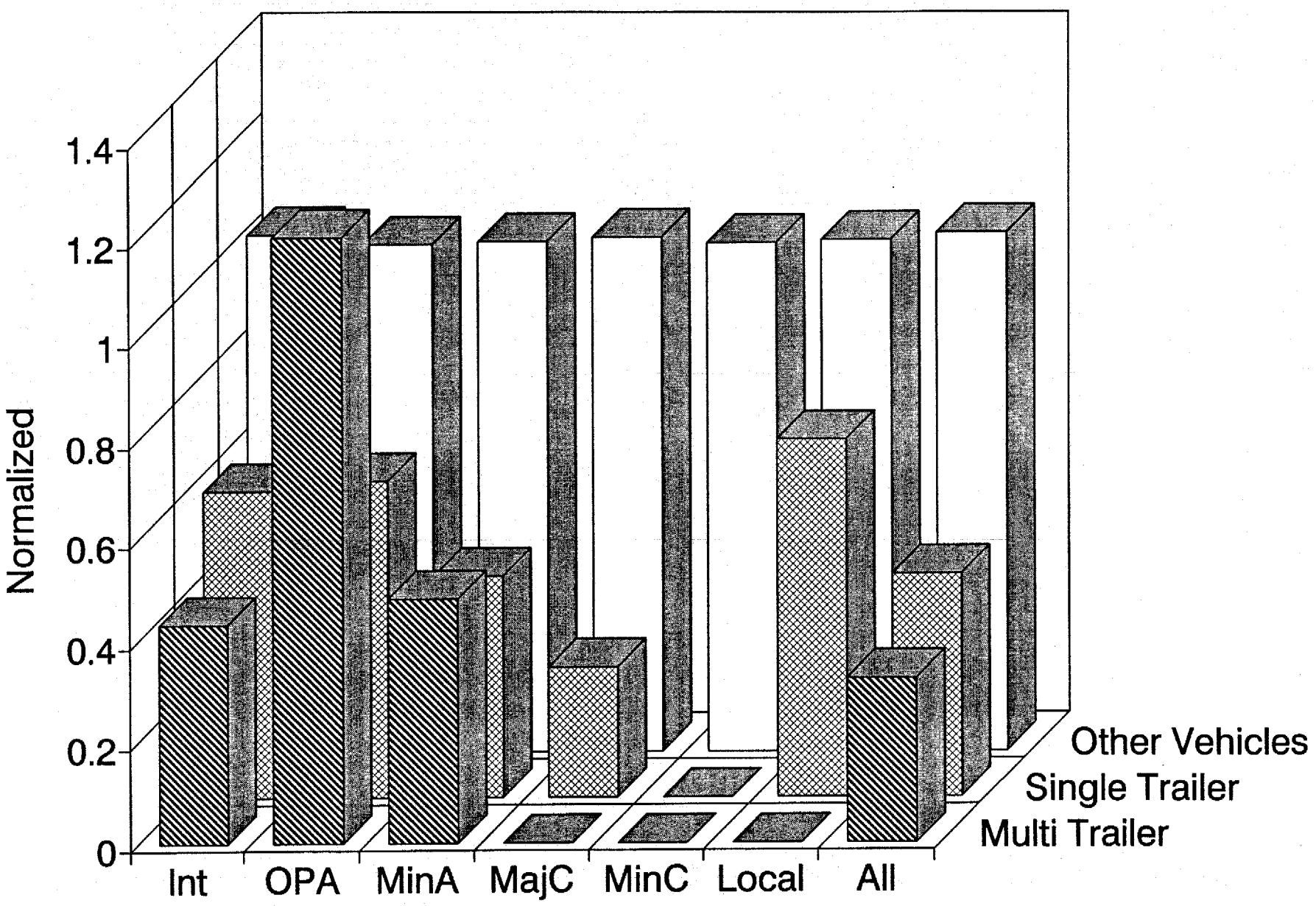

Figure 26

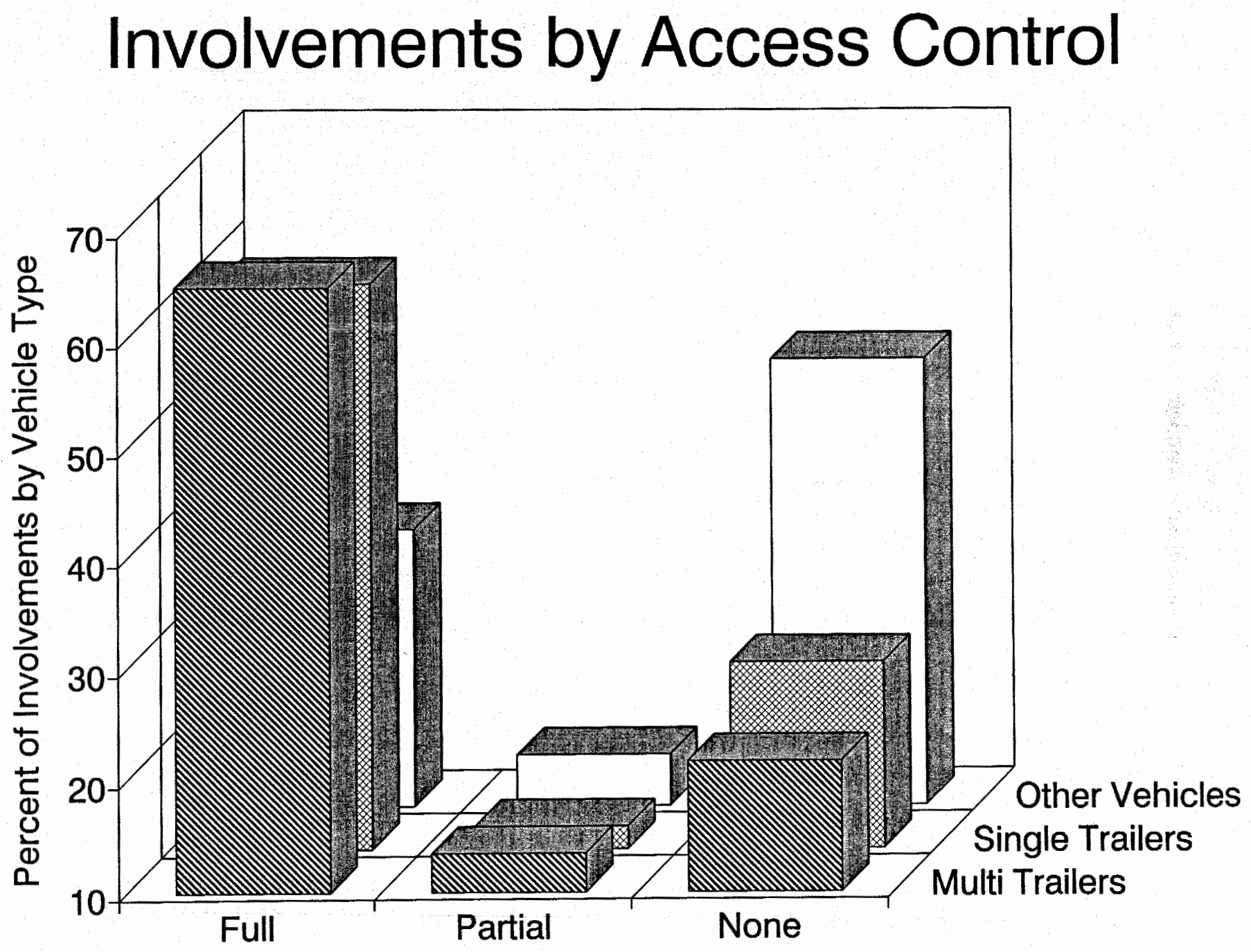
Involvements by Access Control
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
Full
Partial
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 27

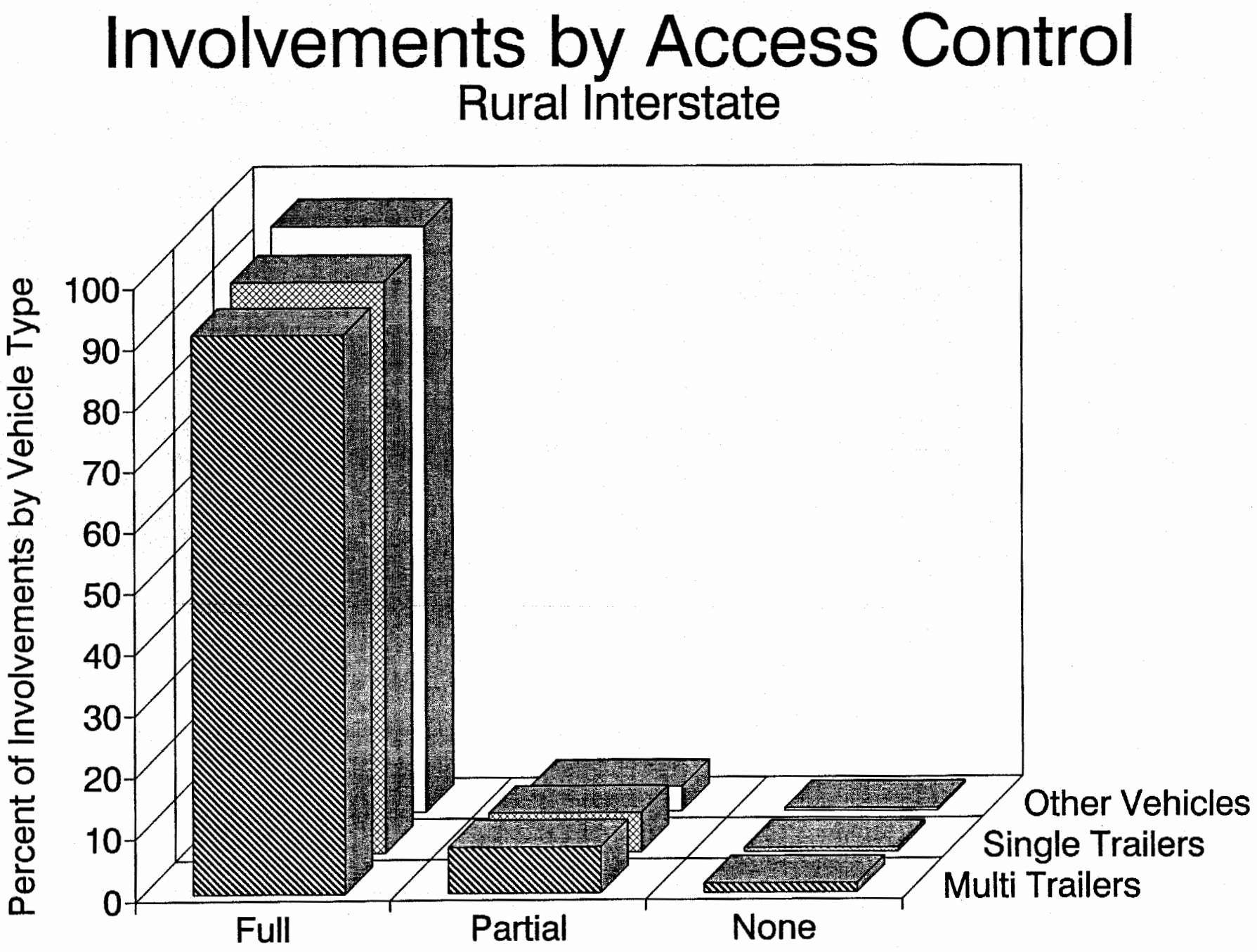
Involvements by Access Control
Rural Interstate
Percent of Involvements by Vehicle Type
100
90
80
70
60
50
40
30
20
10
0
Full
Partial
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 28

Involvements by Access Control

Rural Other

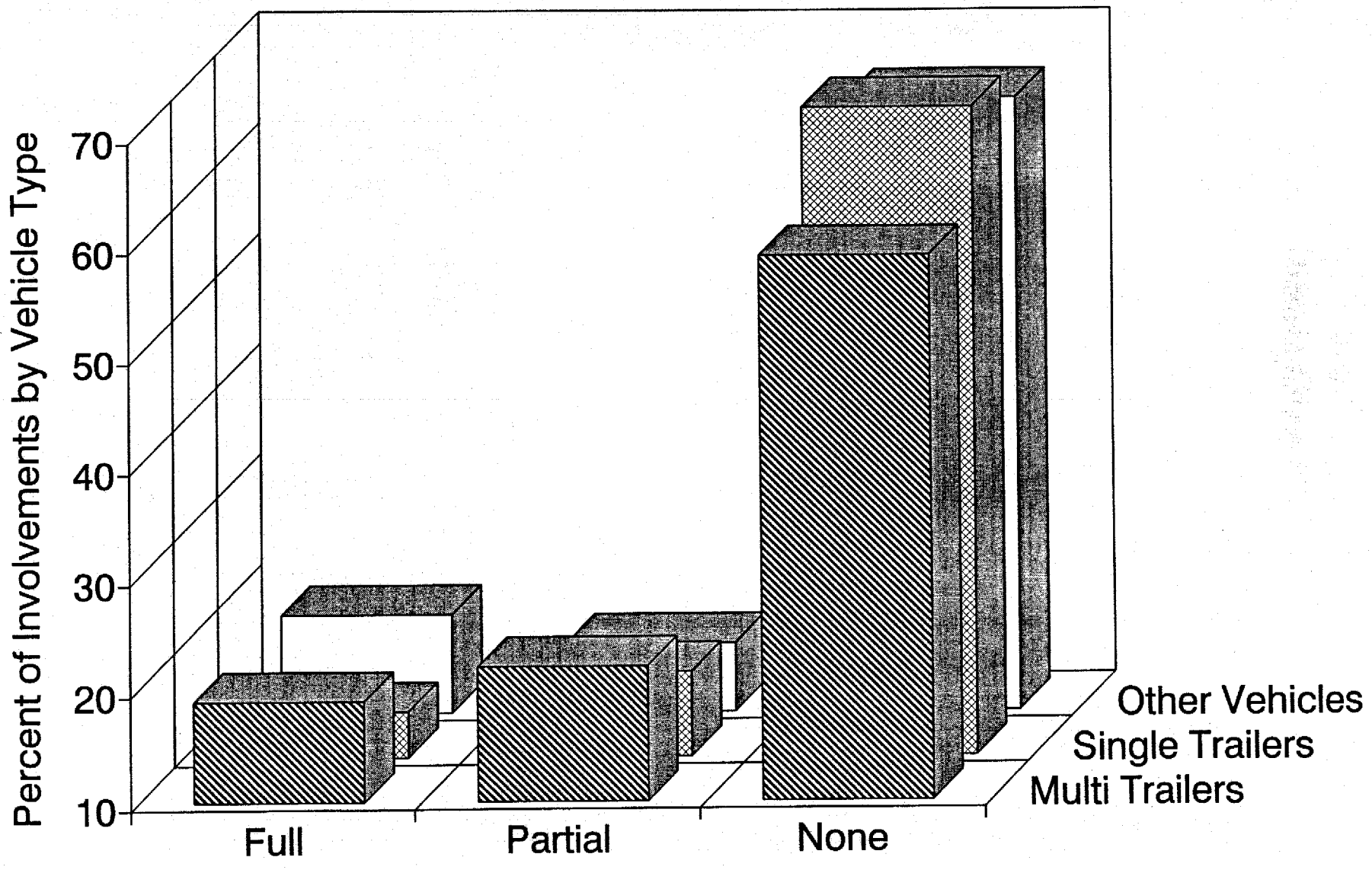

Figure 29

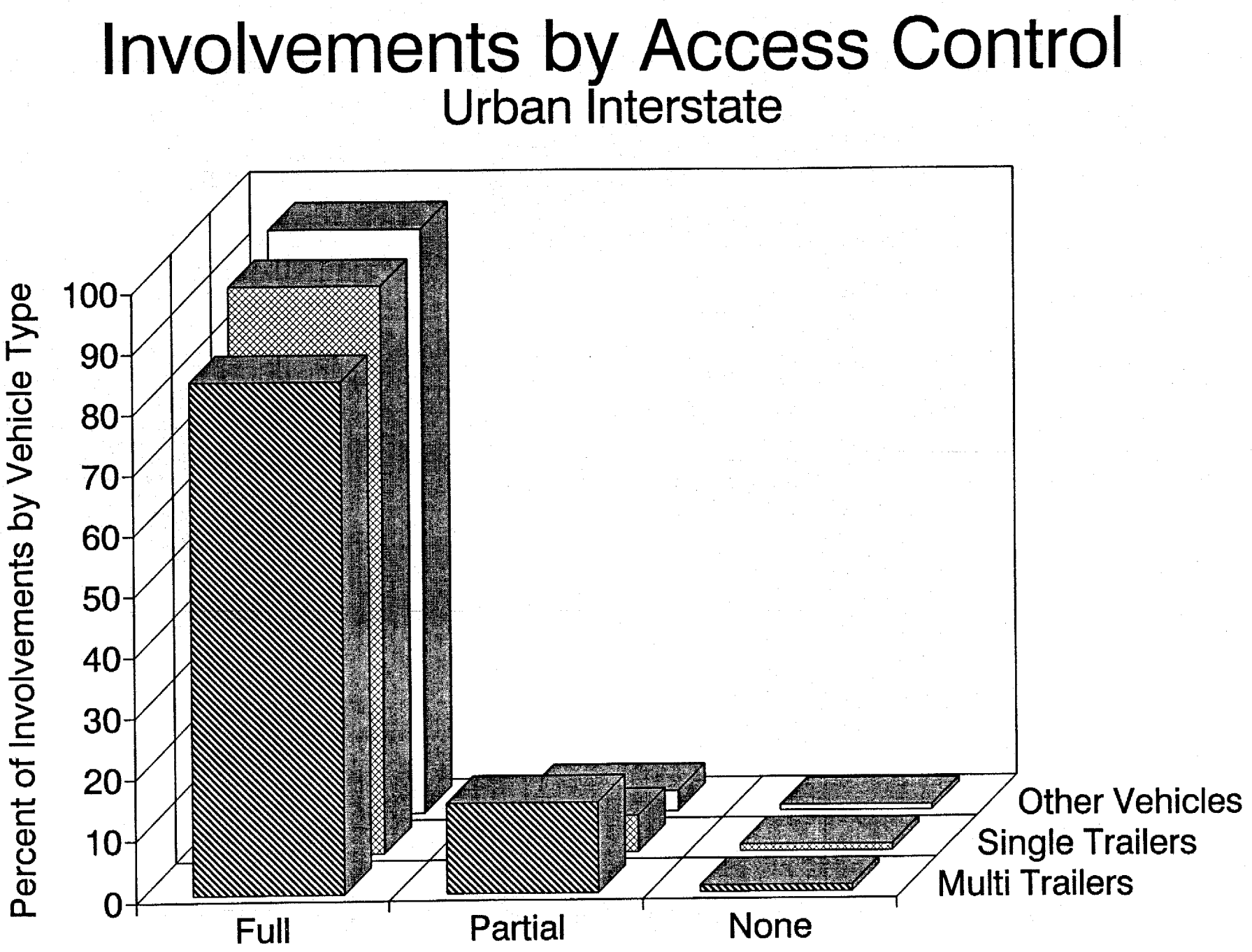
Involvements by Access Control
Urban Interstate
Percent of Involvements by Vehicle Type
100
90
80
70
60
50
40
30
20
10
0
Full
Partial
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 30

Involvements by Access Control

Urban Other

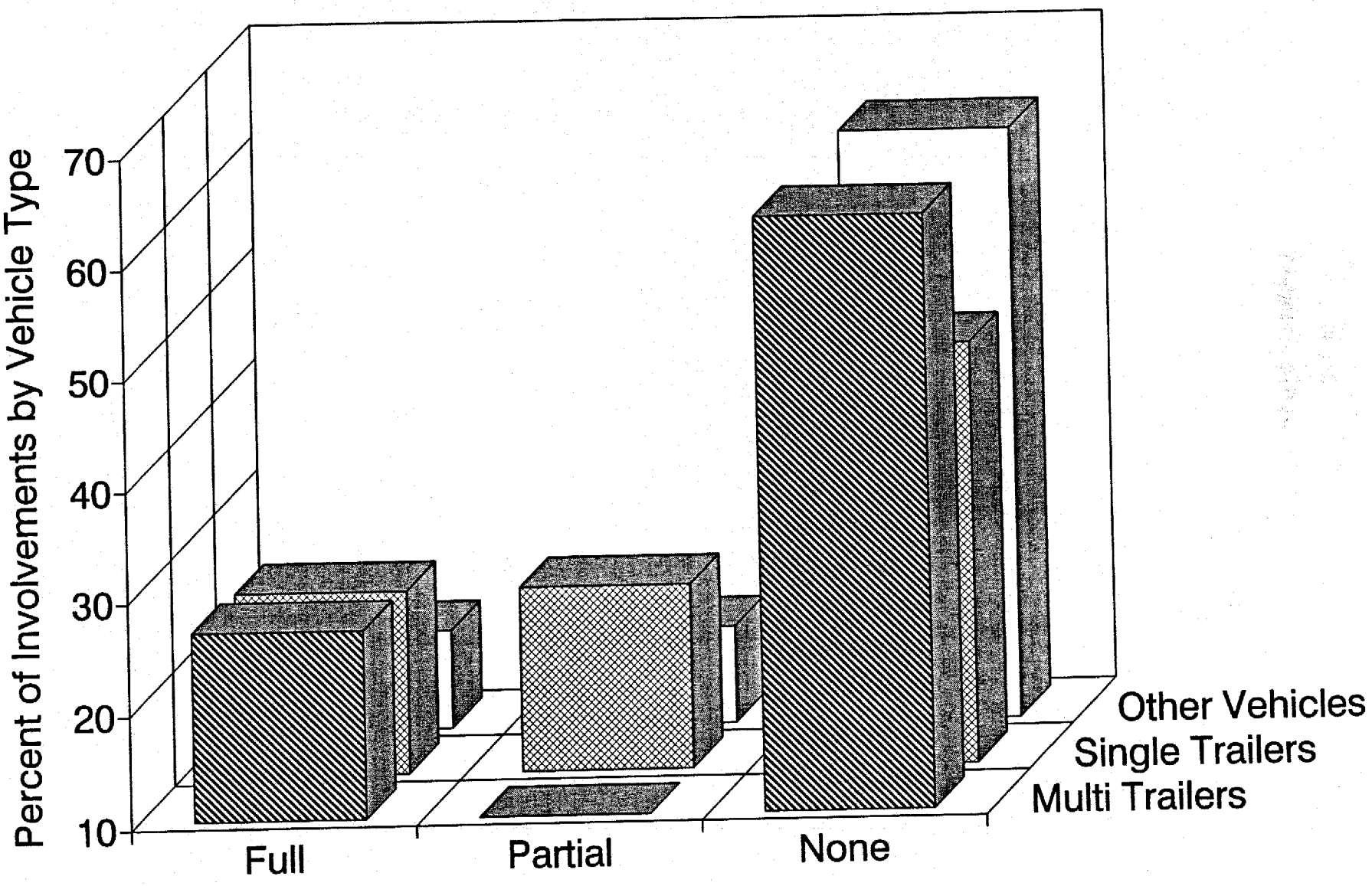

Figure 31

Involvements by Lane Width

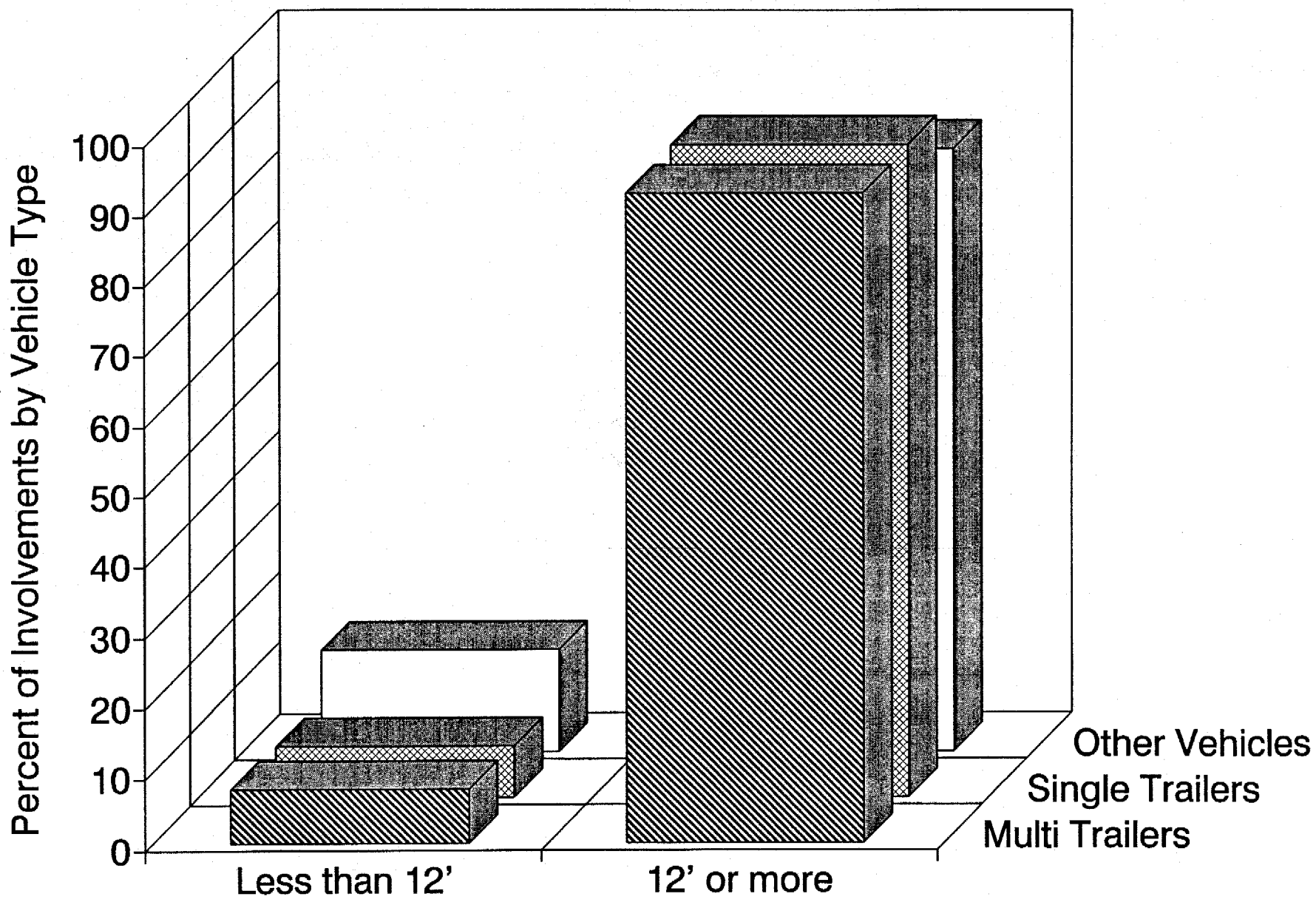

Figure 32

Involvements by Number of Lanes

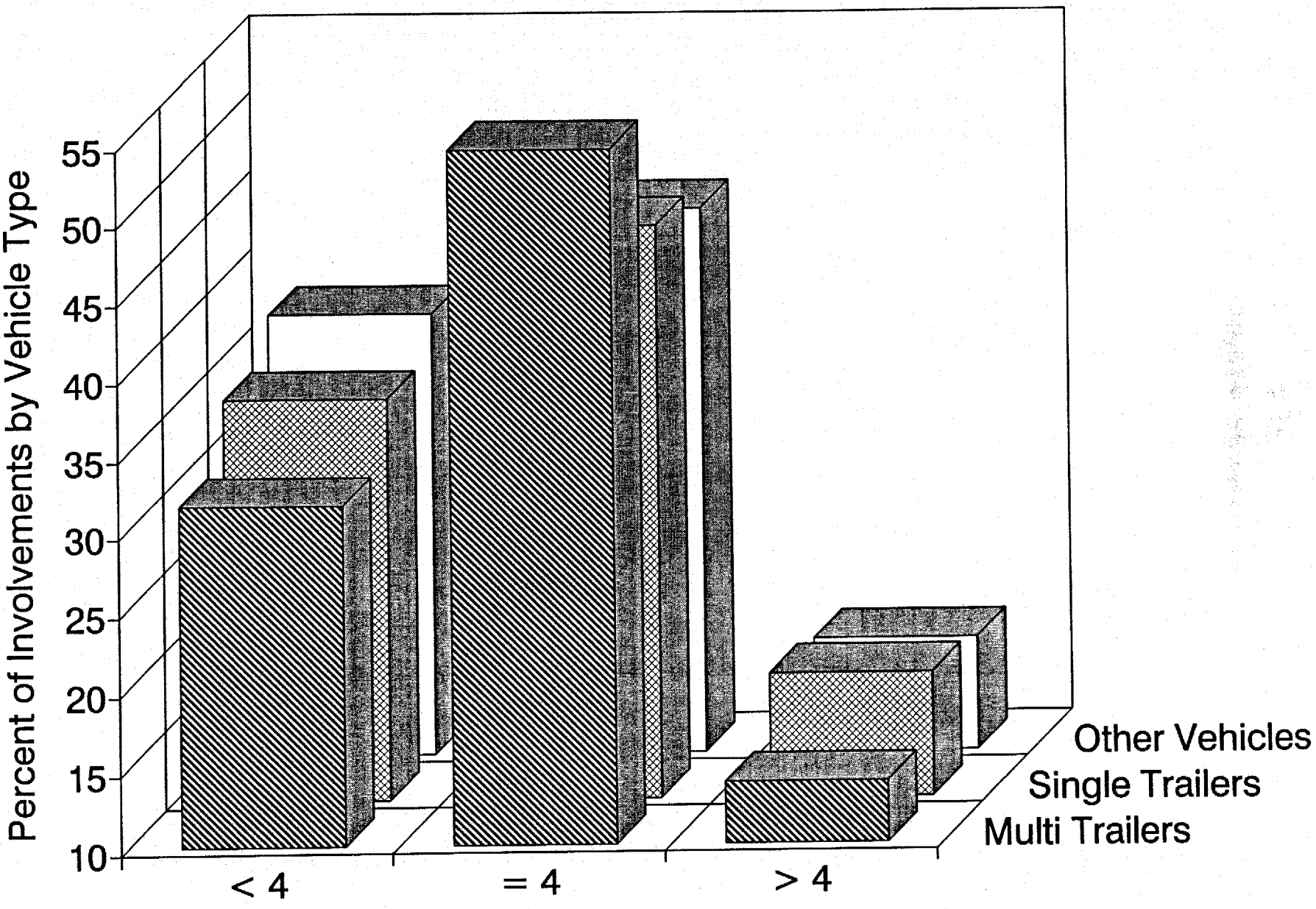

Figure 33

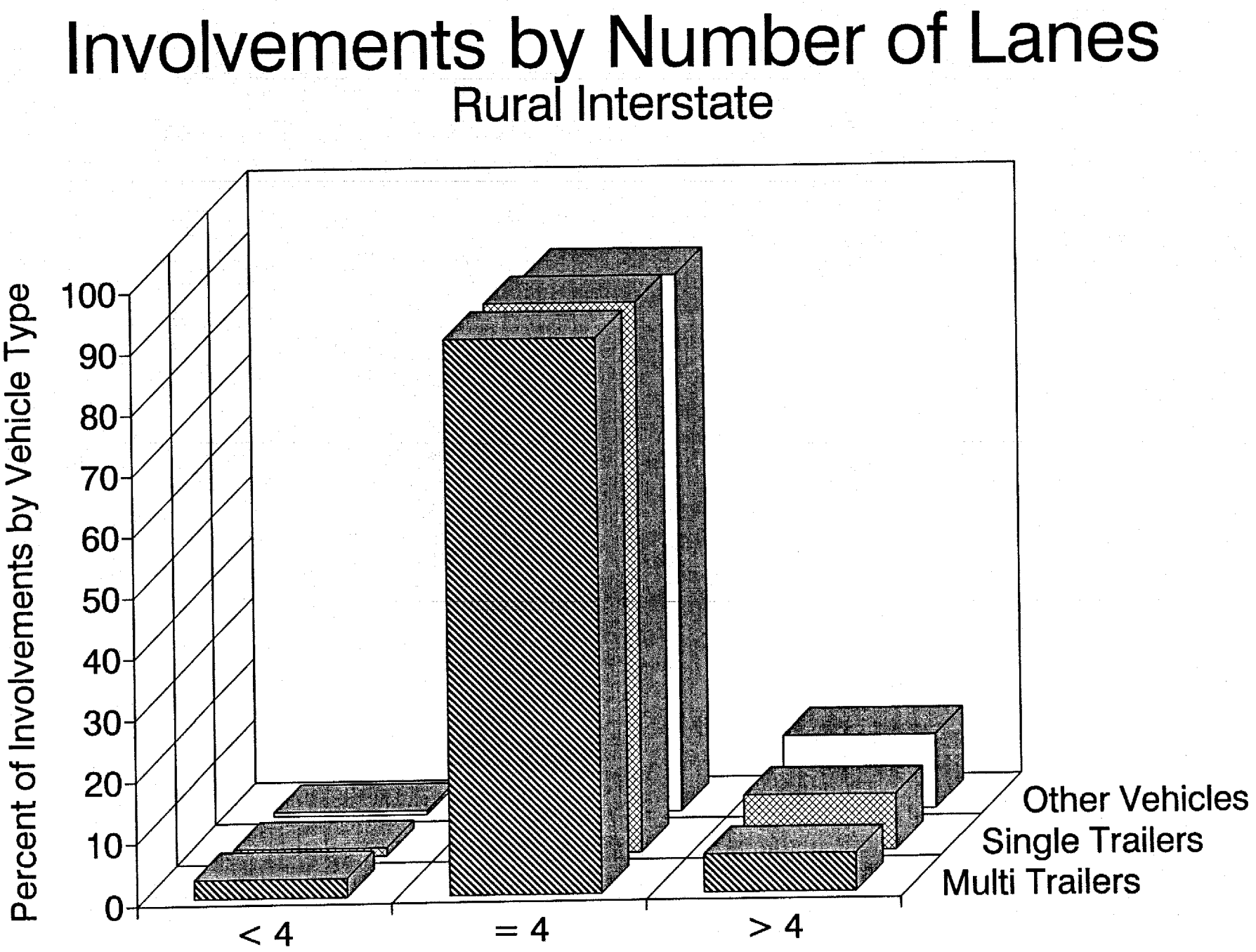
Involvements by Number of Lanes
Rural Interstate
Percent of Involvements by Vehicle Type
100
90
80
70
60
50
40
30
20
10
0
< 4
= 4
> 4
Other Vehicles
Single Trailers
Multi Trailers

Figure 34

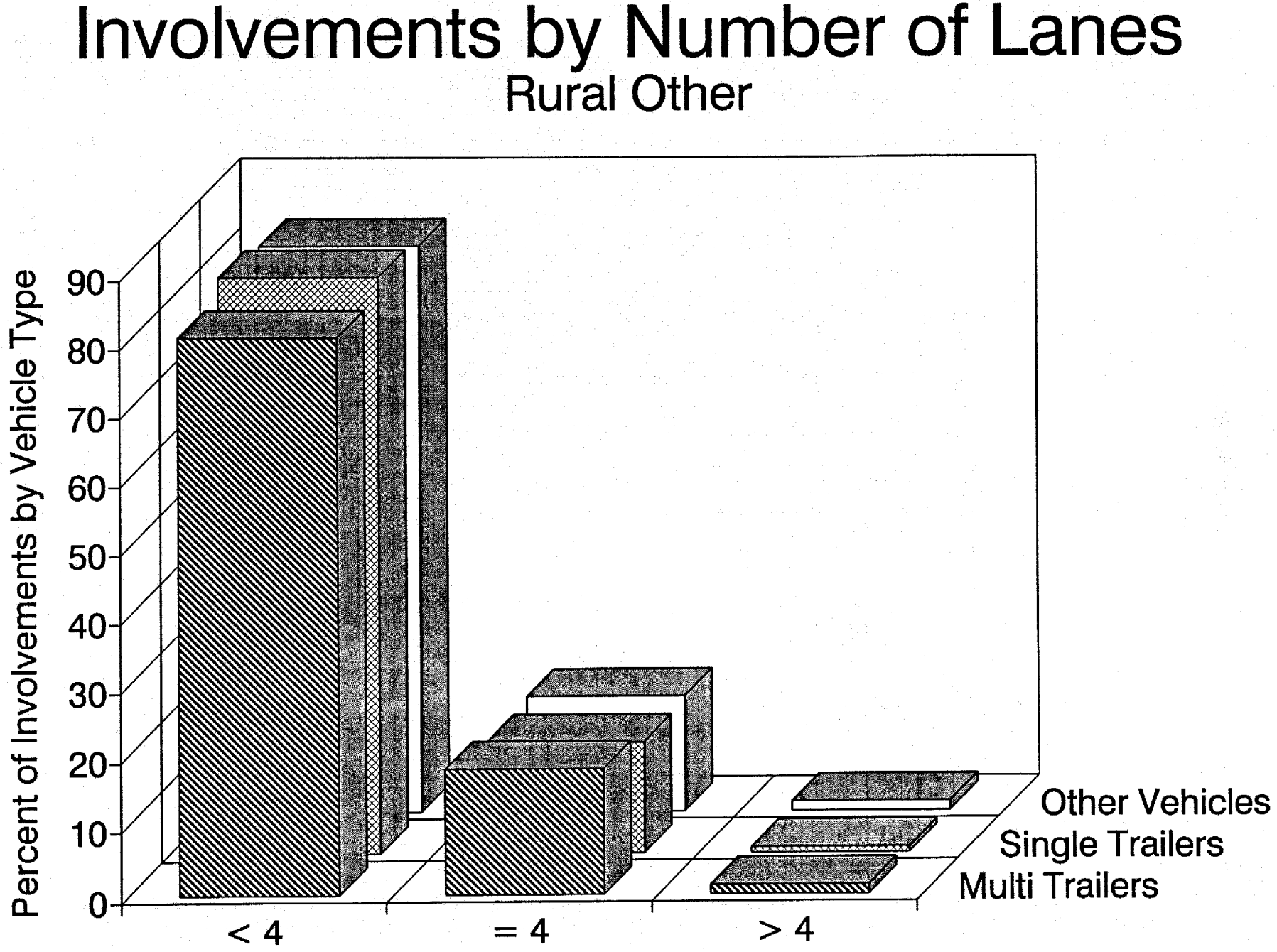
Involvements by Number of Lanes
Rural Other
Percent of Involvements by Vehicle Type
90
80
70
60
50
40
30
20
10
0
< 4
= 4
> 4
Other Vehicles
Single Trailers
Multi Trailers

Figure 35

Involvements by Number of Lanes

Urban Interstate

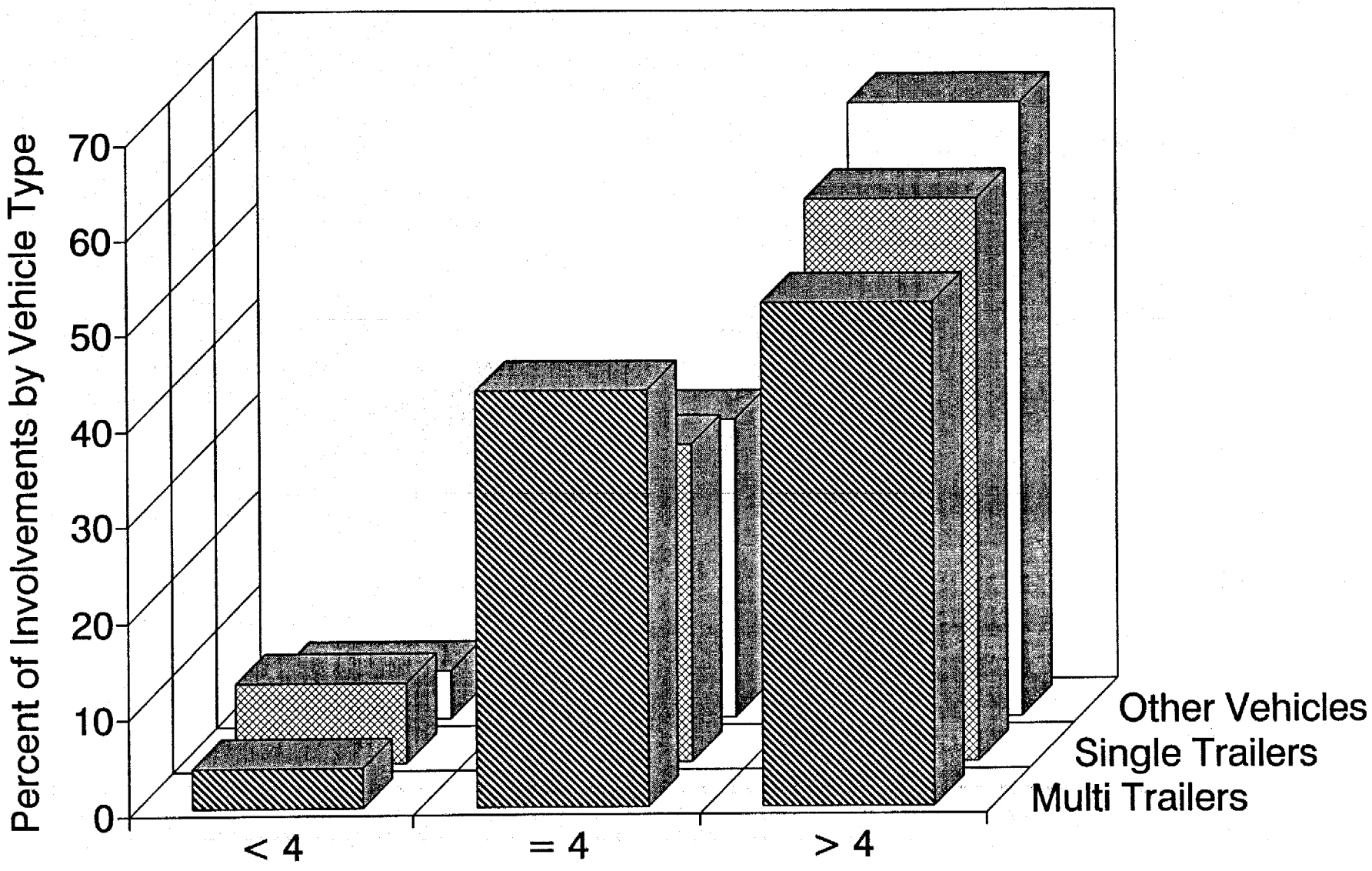

Figure 36

Involvements by Number of Lanes

Urban Other

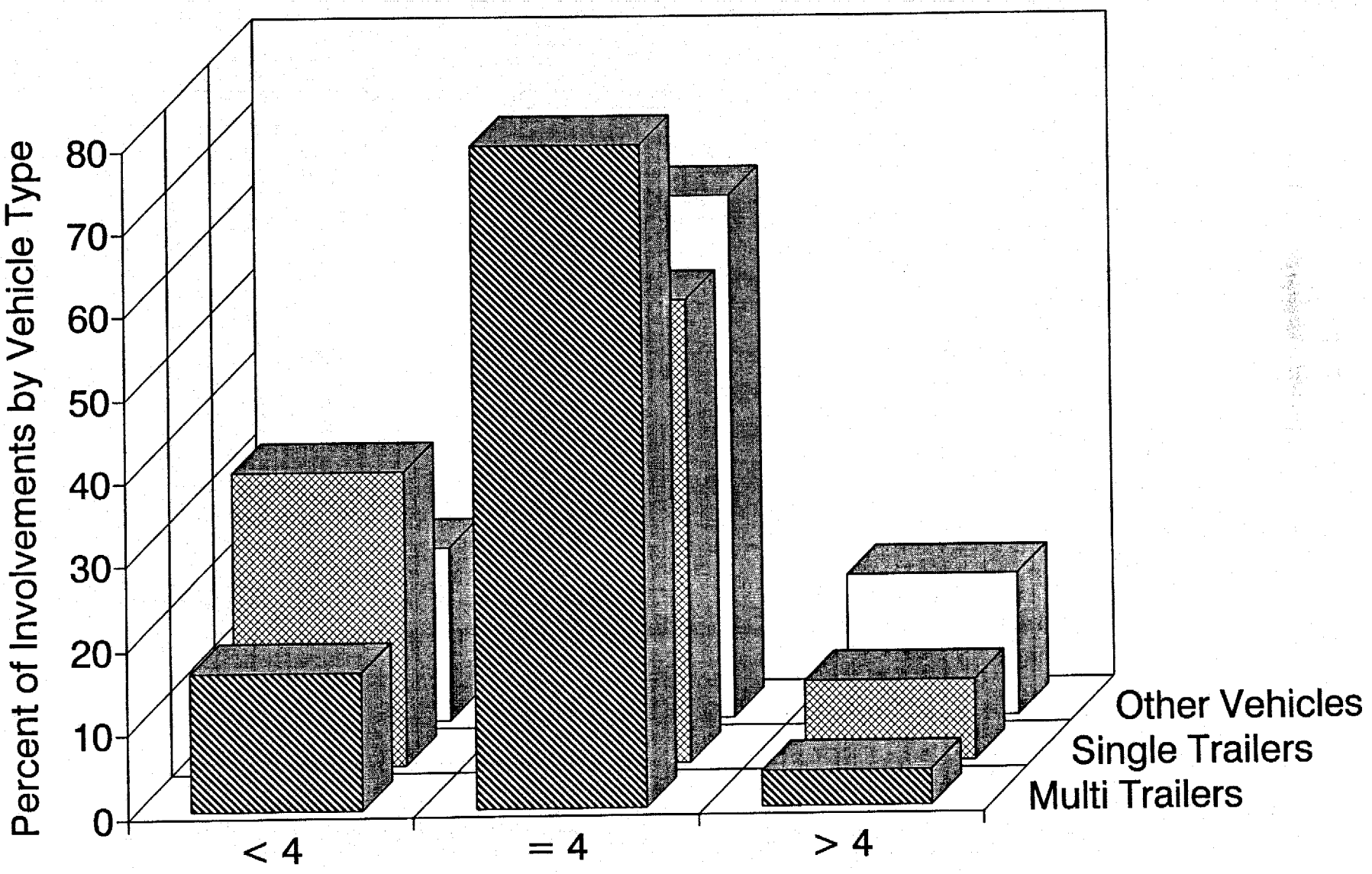

Figure 37

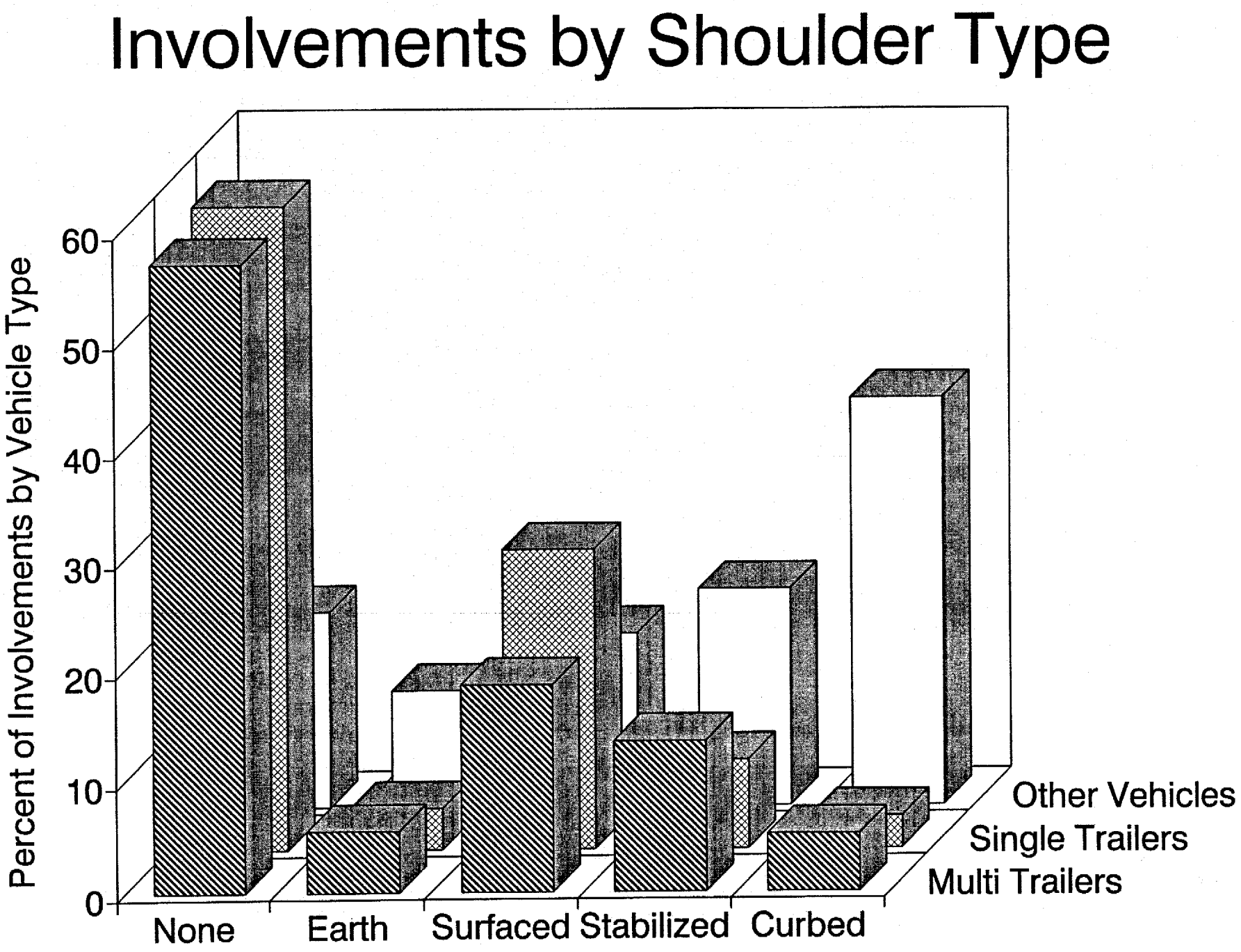
Involvements by Shoulder Type
Percent of Involvements by Vehicle Type
60
50
40
30
20
10
0
None
Earth
Surfaced
Stabilized
Curbed
Other Vehicles
Single Trailers
Multi Trailers

Figure 38

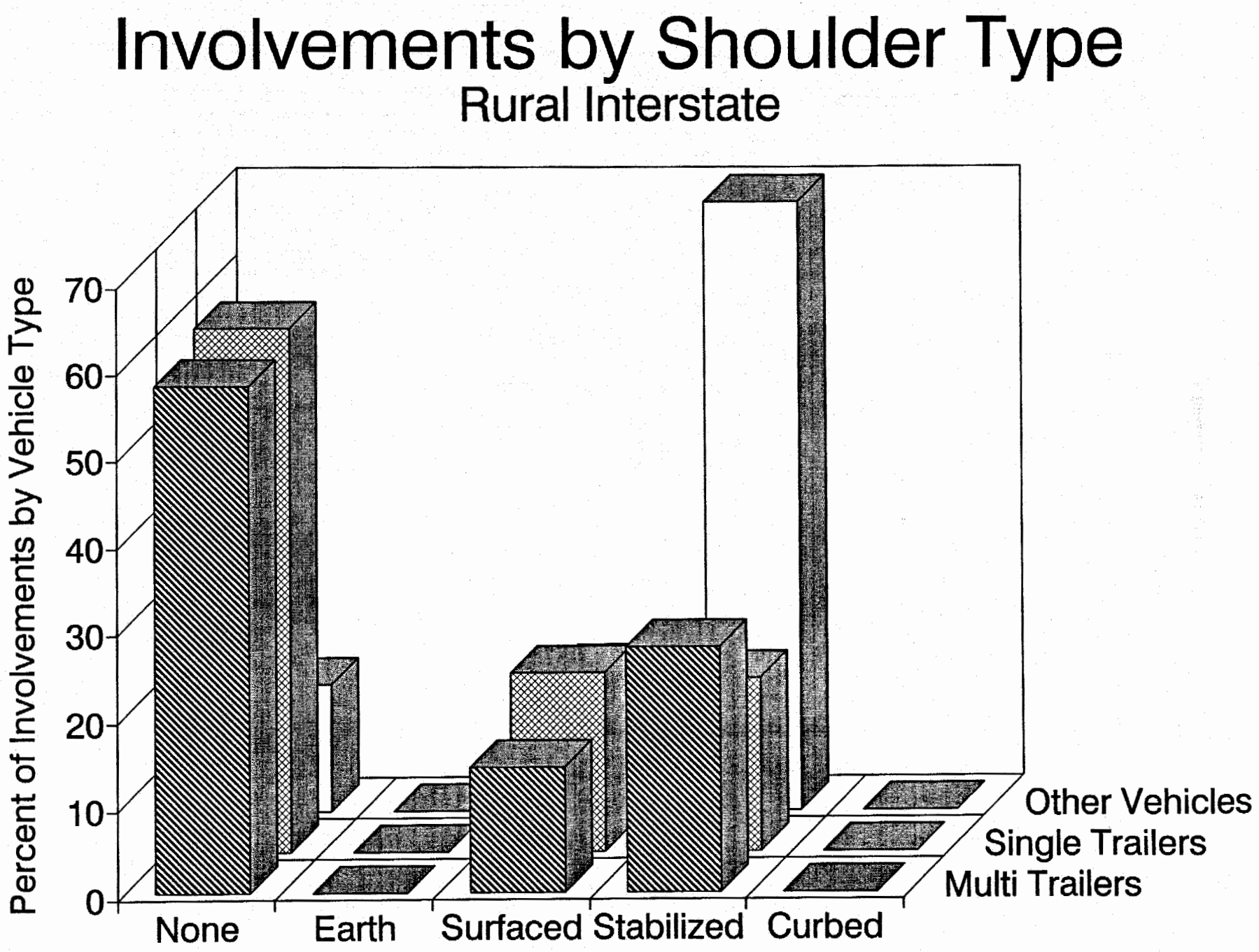
Involvements by Shoulder Type
Rural Interstate
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
0
None
Earth
Surfaced
Stabilized
Curbed
Other Vehicles
Single Trailers
Multi Trailers

Figure 39

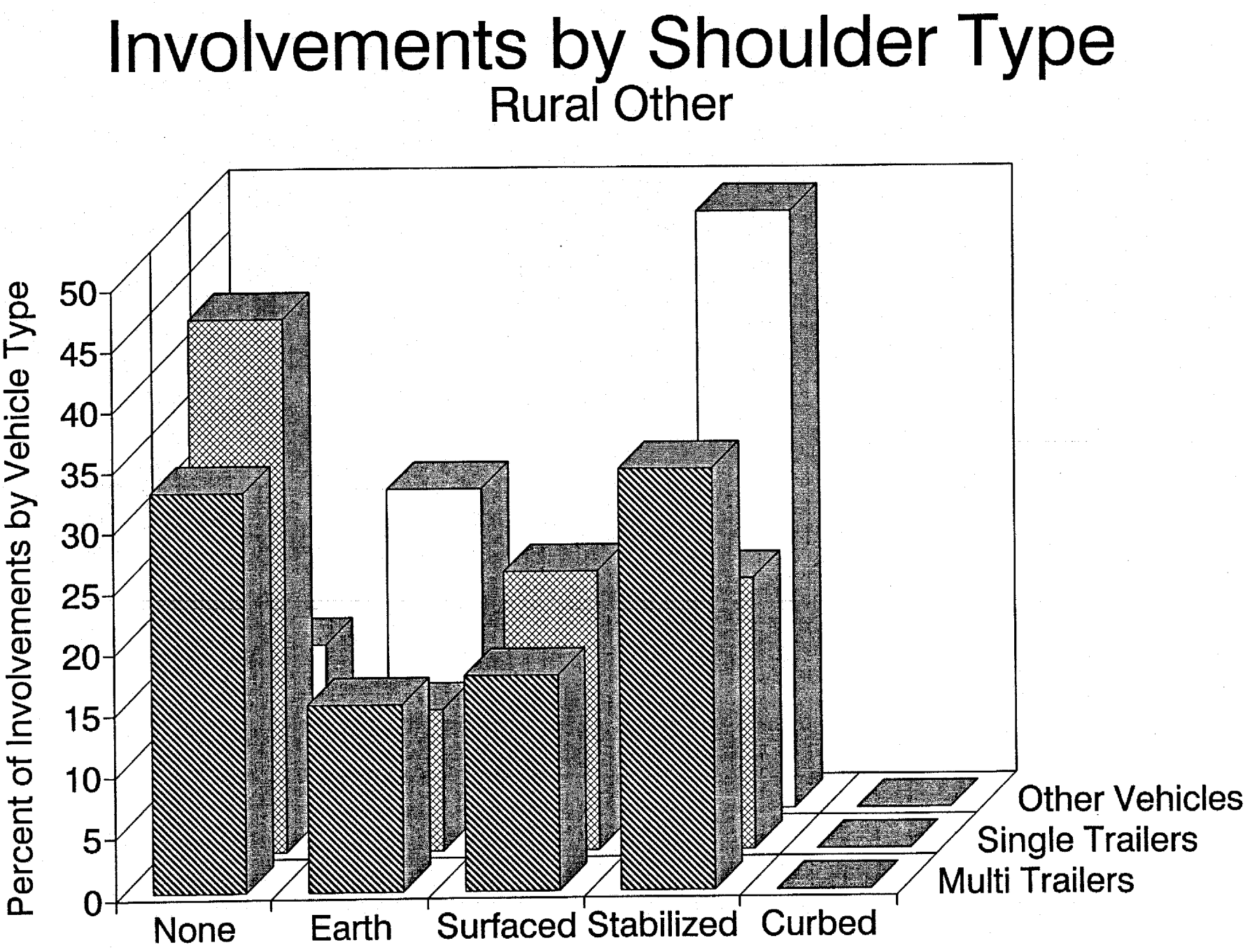
Involvements by Shoulder Type
Rural Other
Percent of Involvements by Vehicle Type
0
5
10
15
20
25
30
35
40
45
50
None
Earth
Surfaced
Stabilized
Curbed
Other Vehicles
Single Trailers
Multi Trailers

Figure 40

Involvements by Shoulder Type

Urban Interstate

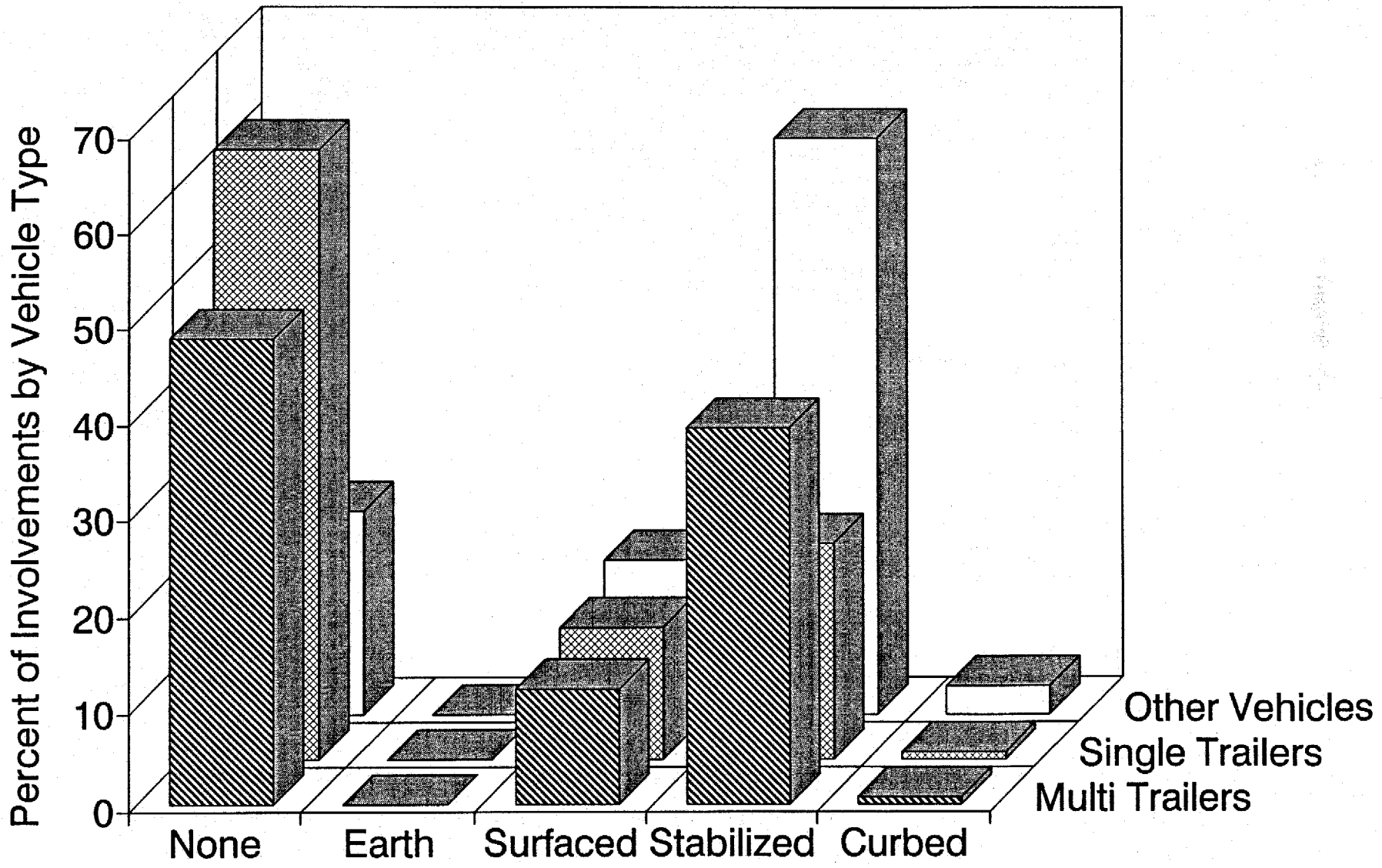

Figure 41

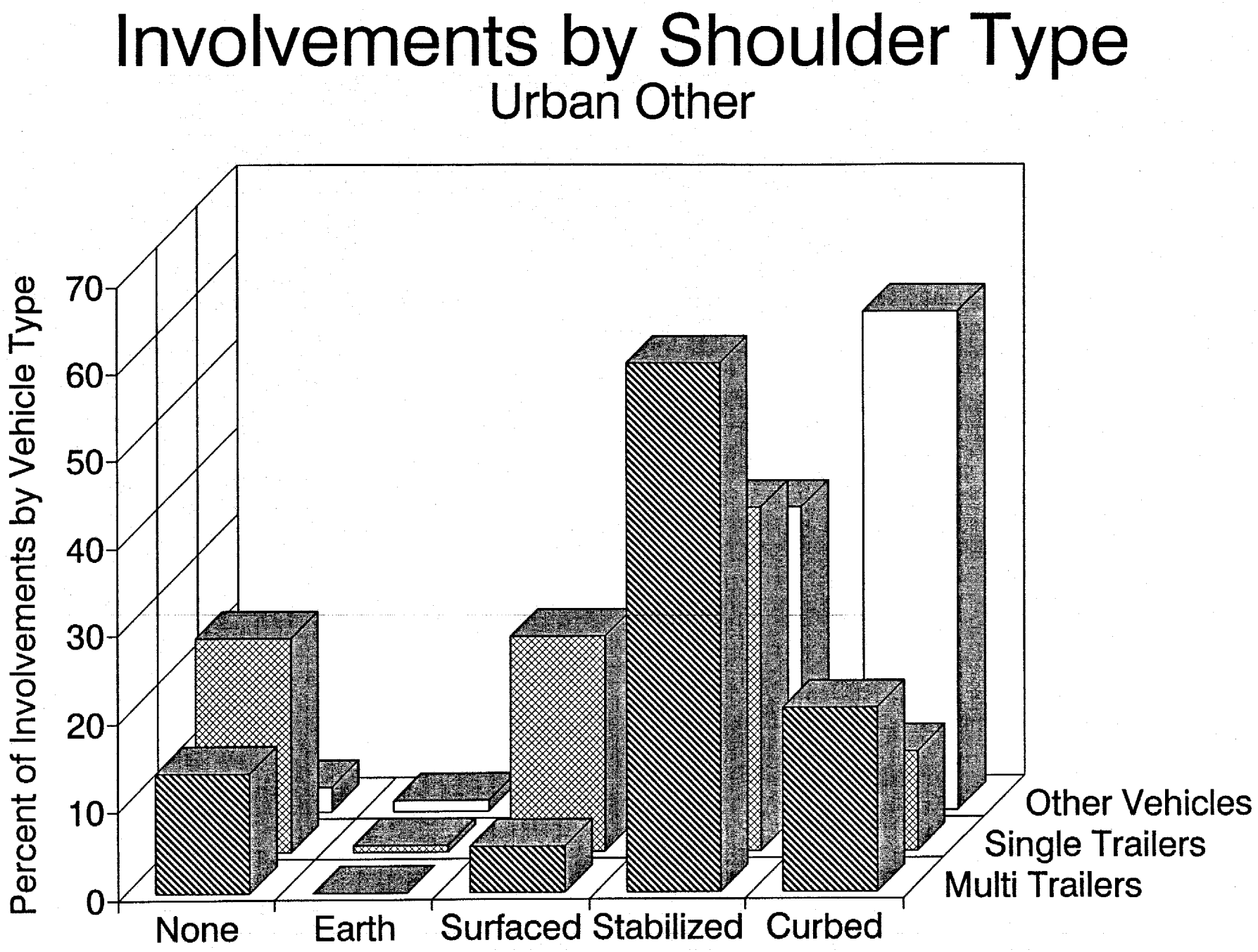
Involvements by Shoulder Type
Urban Other
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
0
None
Earth
Surfaced
Stabilized
Curbed
Other Vehicles
Single Trailers
Multi Trailers

Figure 42

Involvements by Right Shoulder Width

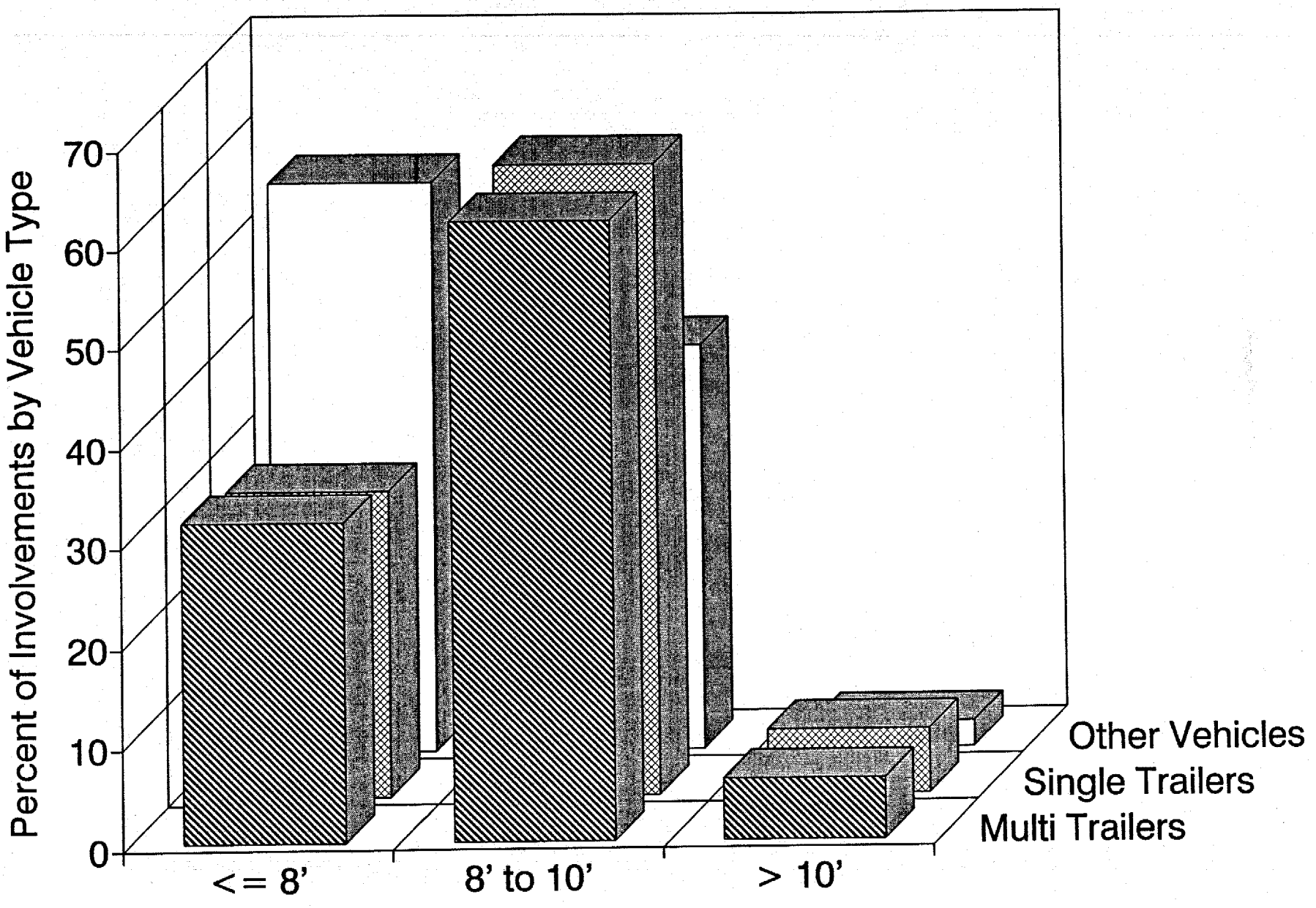

Figure 43

Involvements by Right Shoulder Width

Rural Interstate

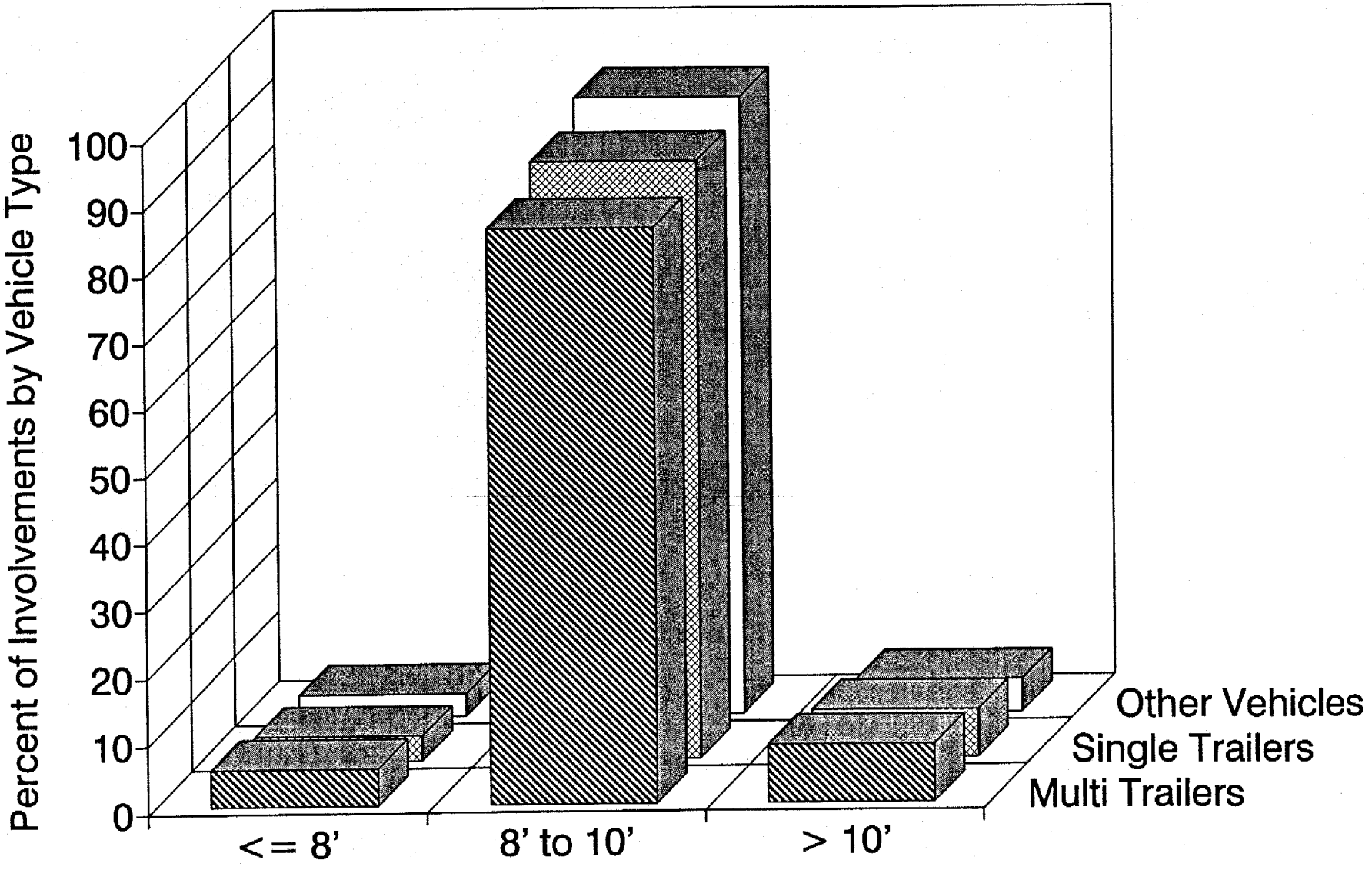

Figure 44

Involvements by Right Shoulder Width

Rural Other

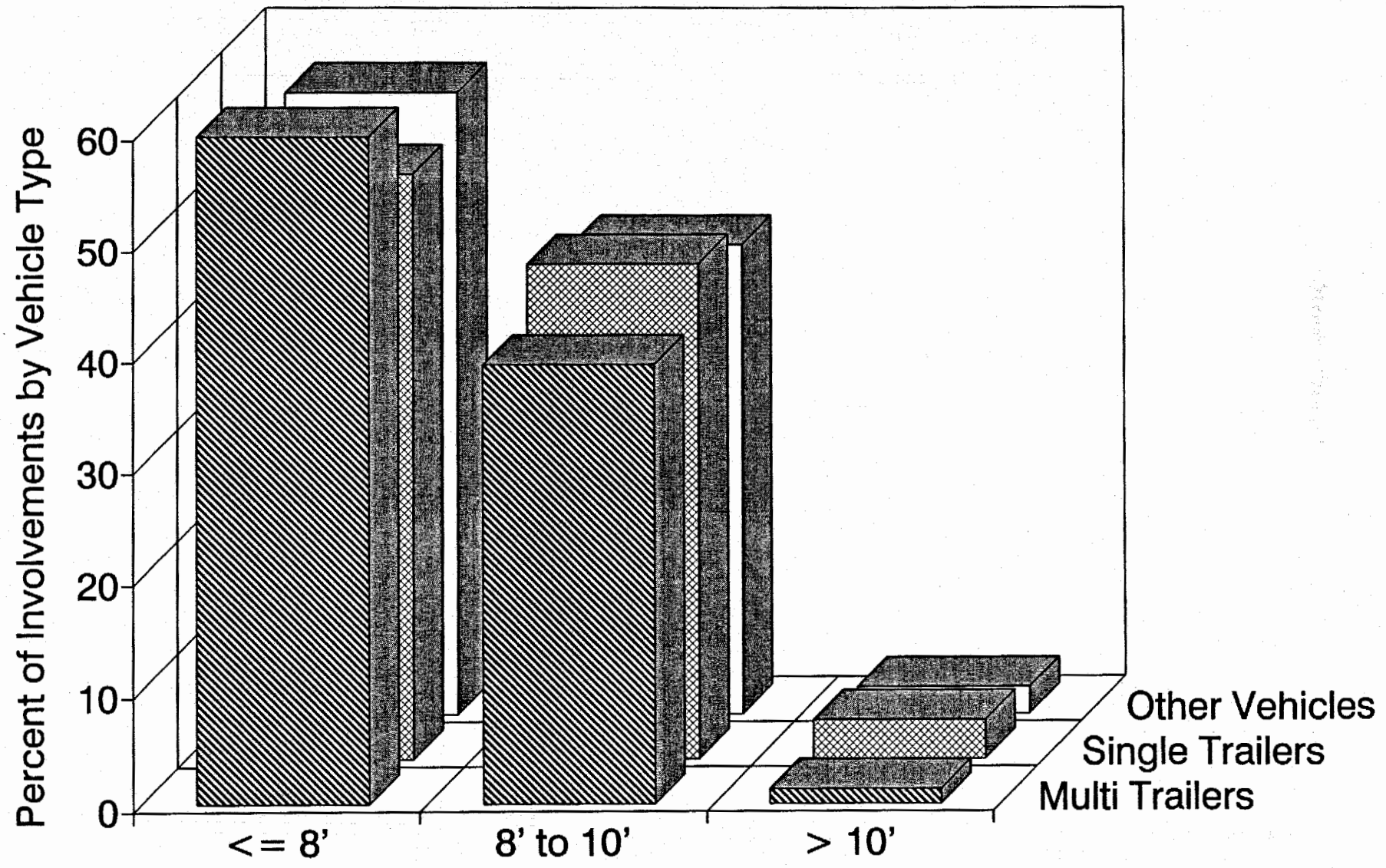

Figure 45

Involvements by Right Shoulder Width

Urban Interstate

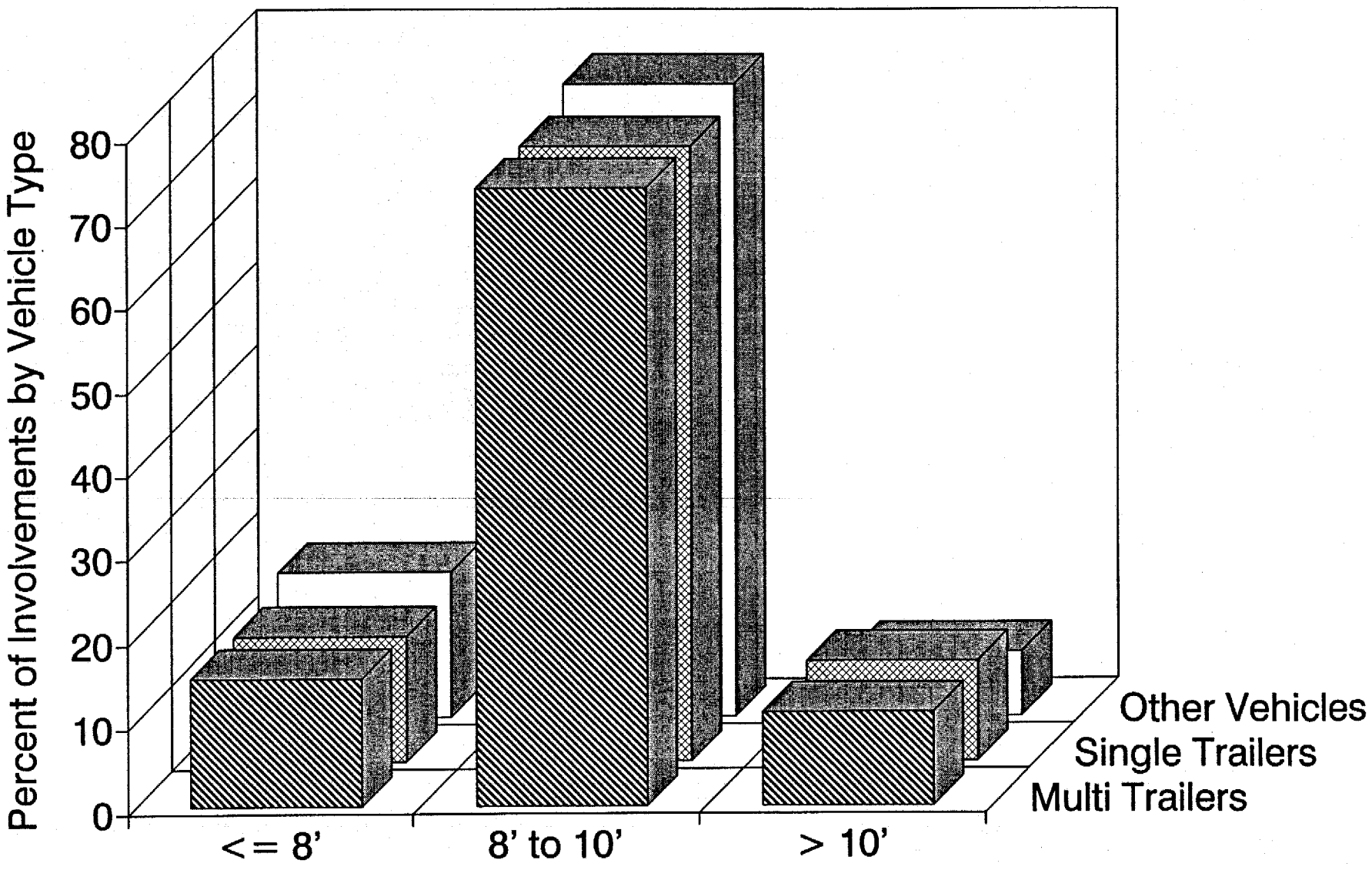

Figure 46

Involvements by Right Shoulder Width

Urban Other

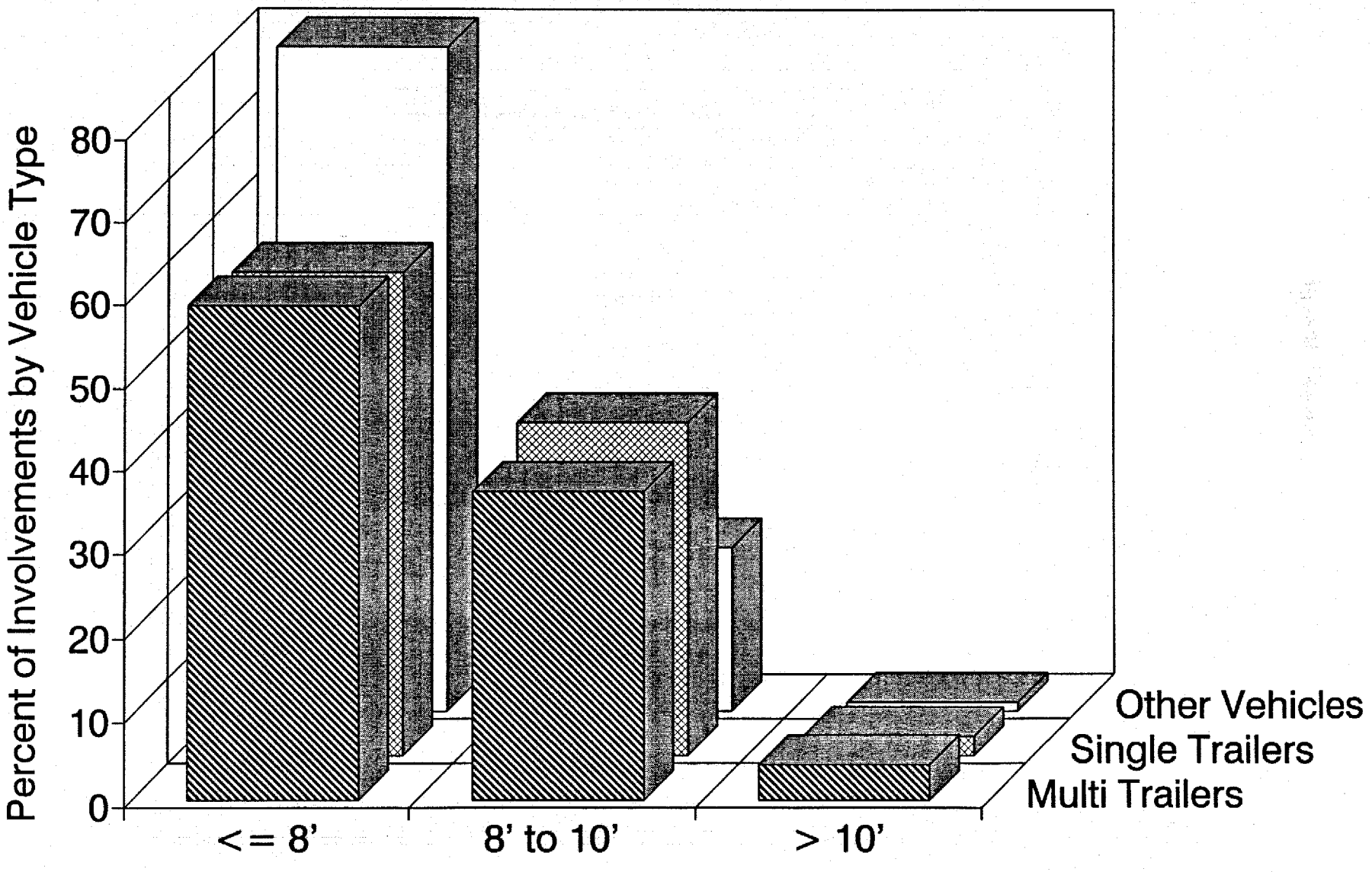

Figure 47

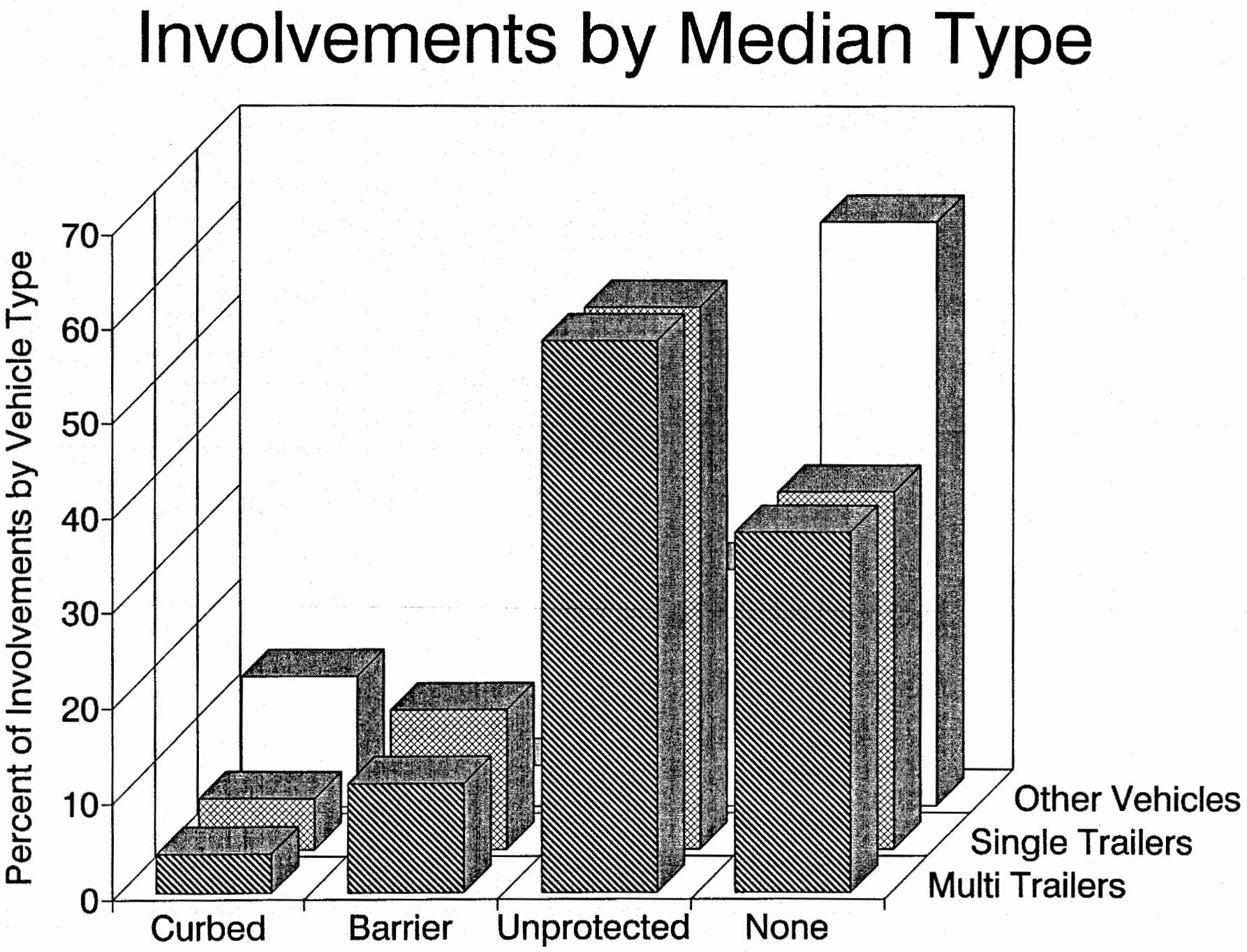
Involvements by Median Type
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
0
Curbed
Barrier
Unprotected
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 48

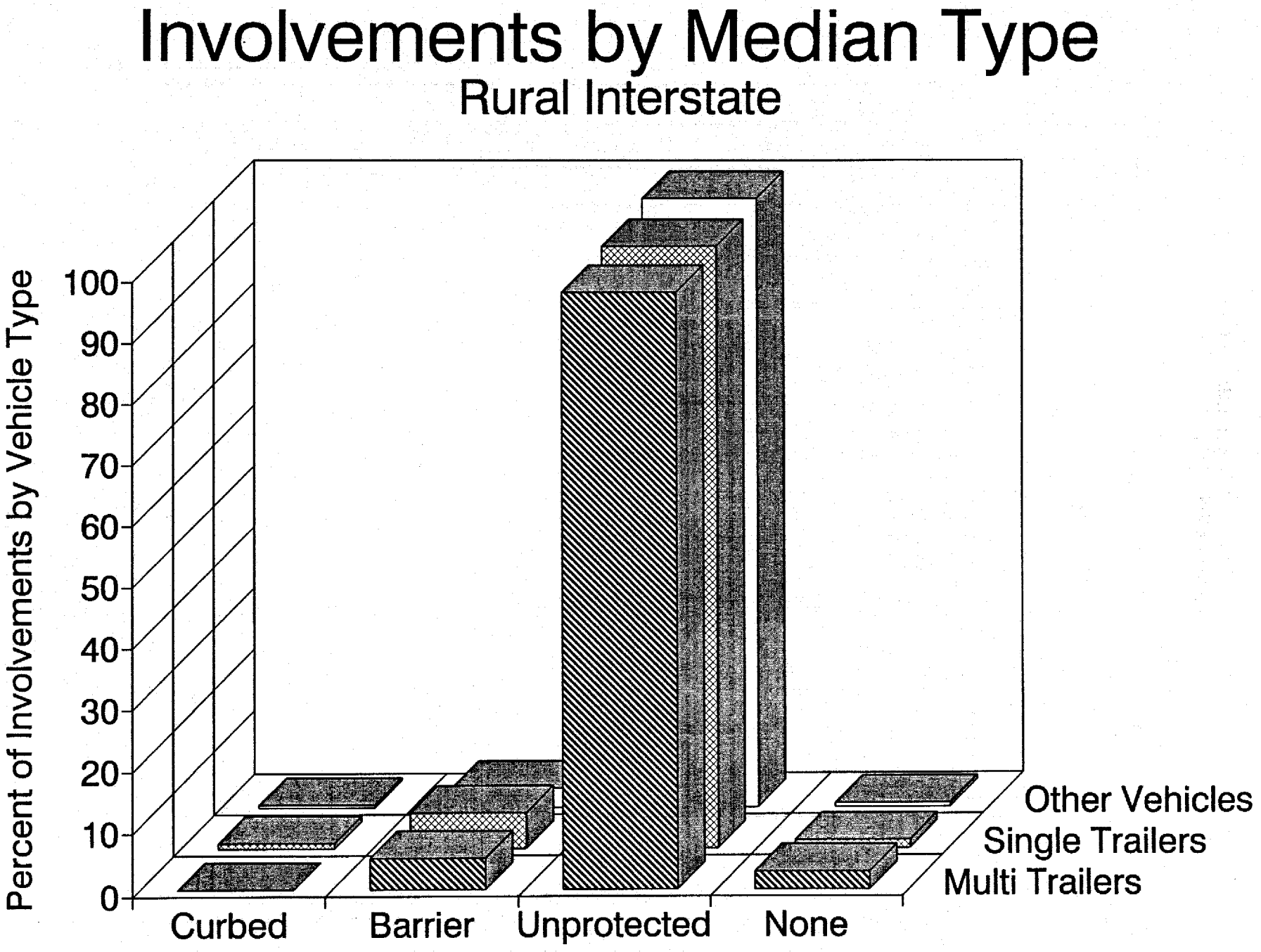
Involvements by Median Type
Rural Interstate
Percent of Involvements by Vehicle Type
100
90
80
70
60
50
40
30
20
10
0
Curbed
Barrier
Unprotected
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 49

Involvements by Median Type

Rural Other

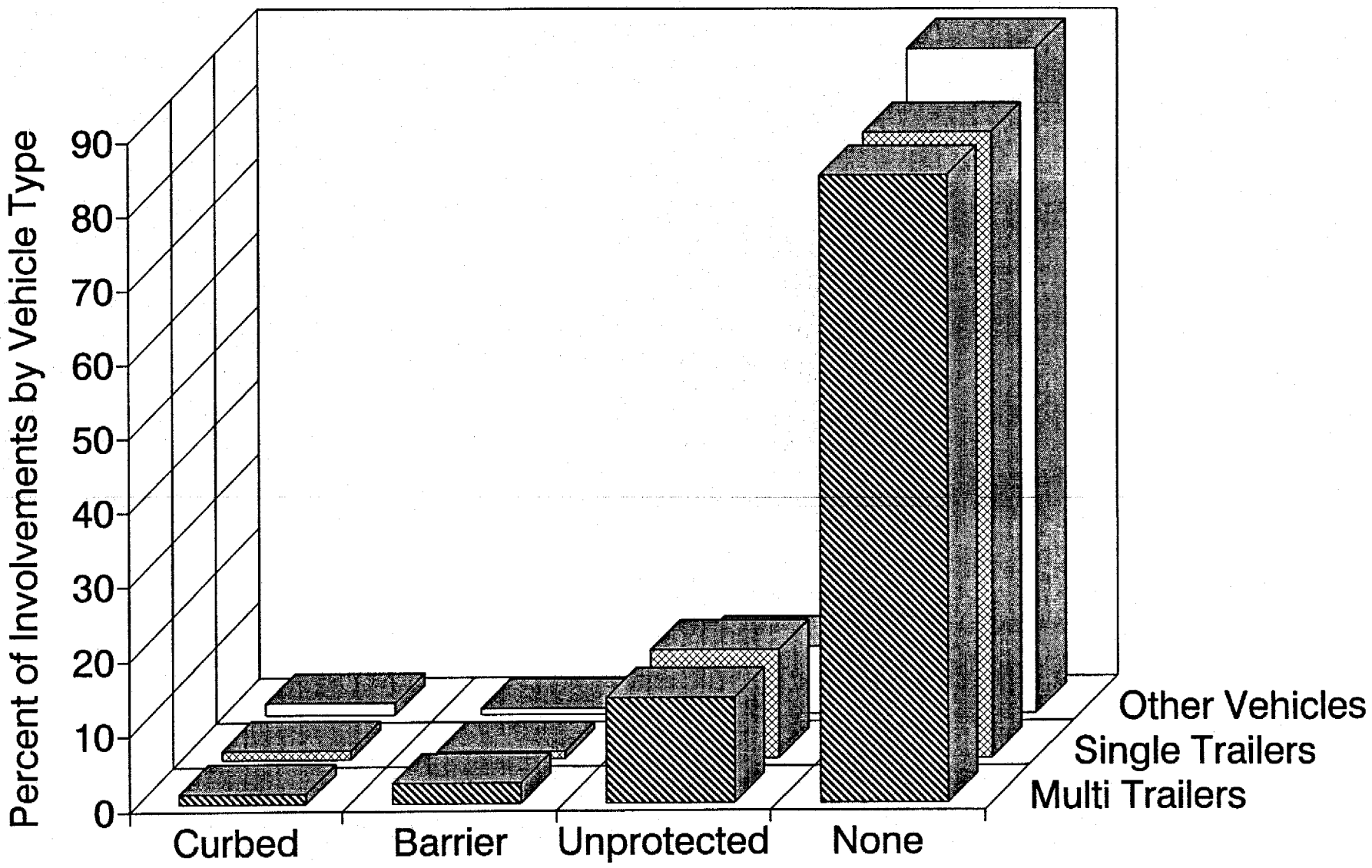

Figure 50

Involvements by Median Type

Urban Interstate

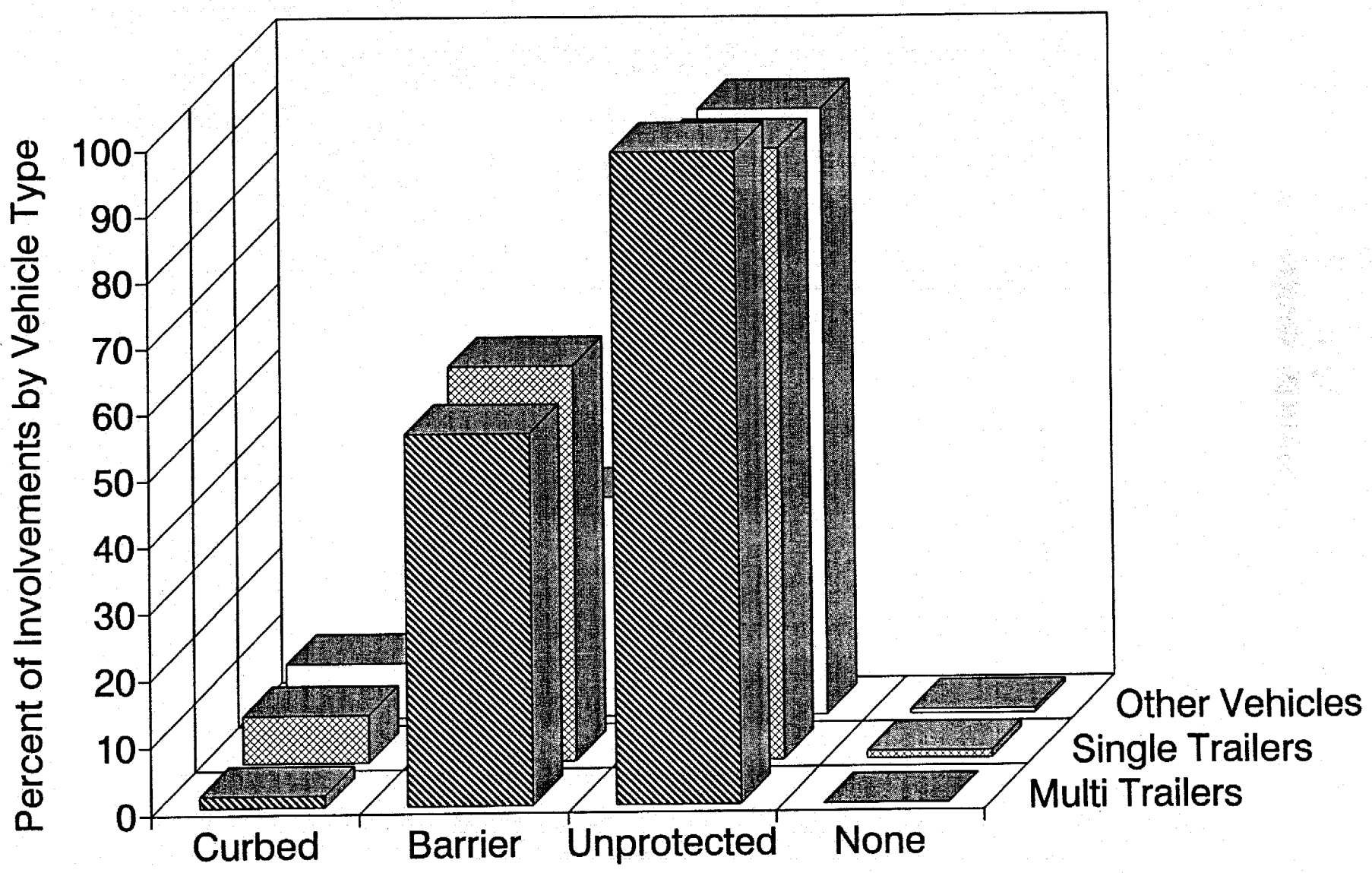

Figure 51

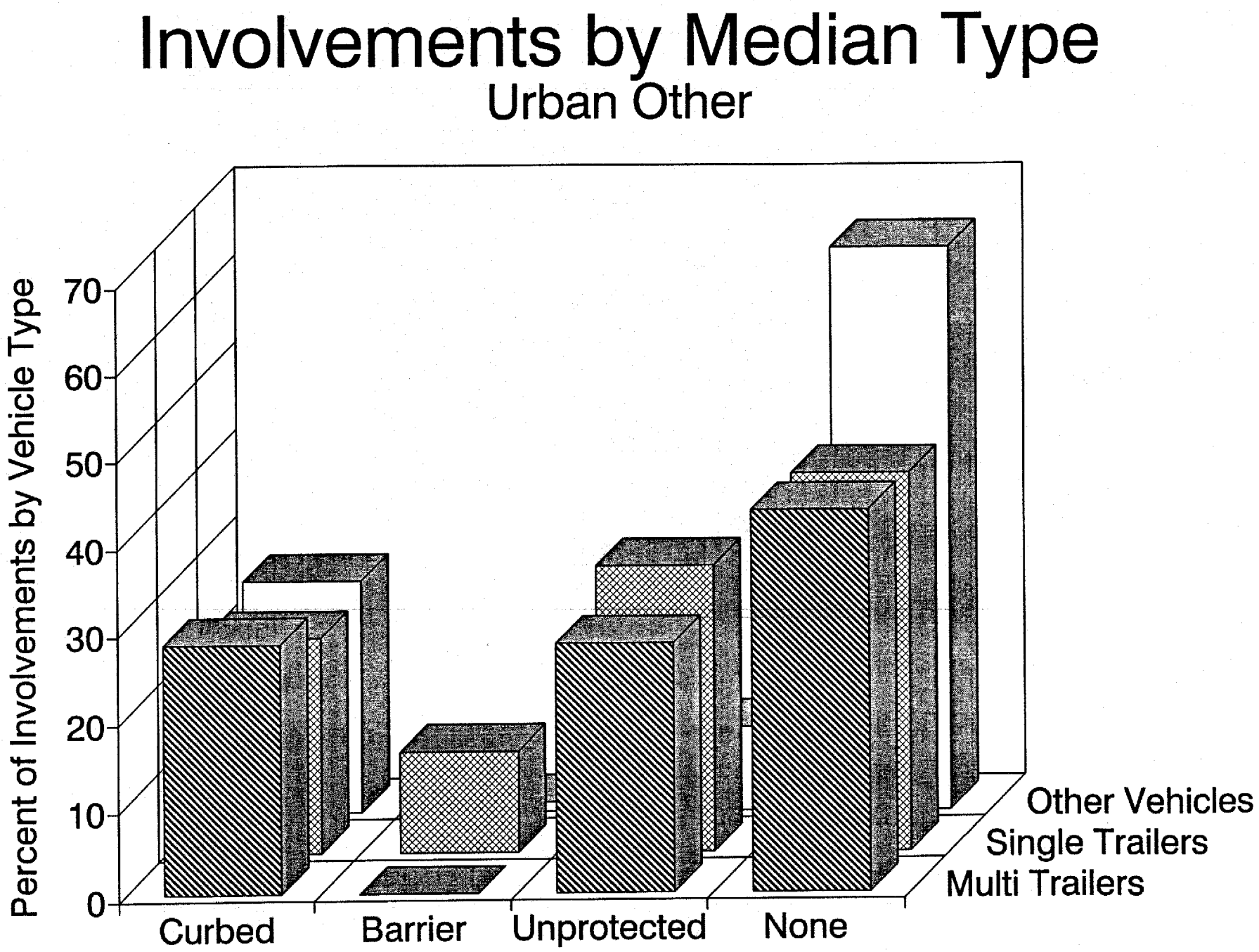
Involvements by Median Type
Urban Other
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
0
Curbed
Barrier
Unprotected
None
Other Vehicles
Single Trailers
Multi Trailers

Figure 52

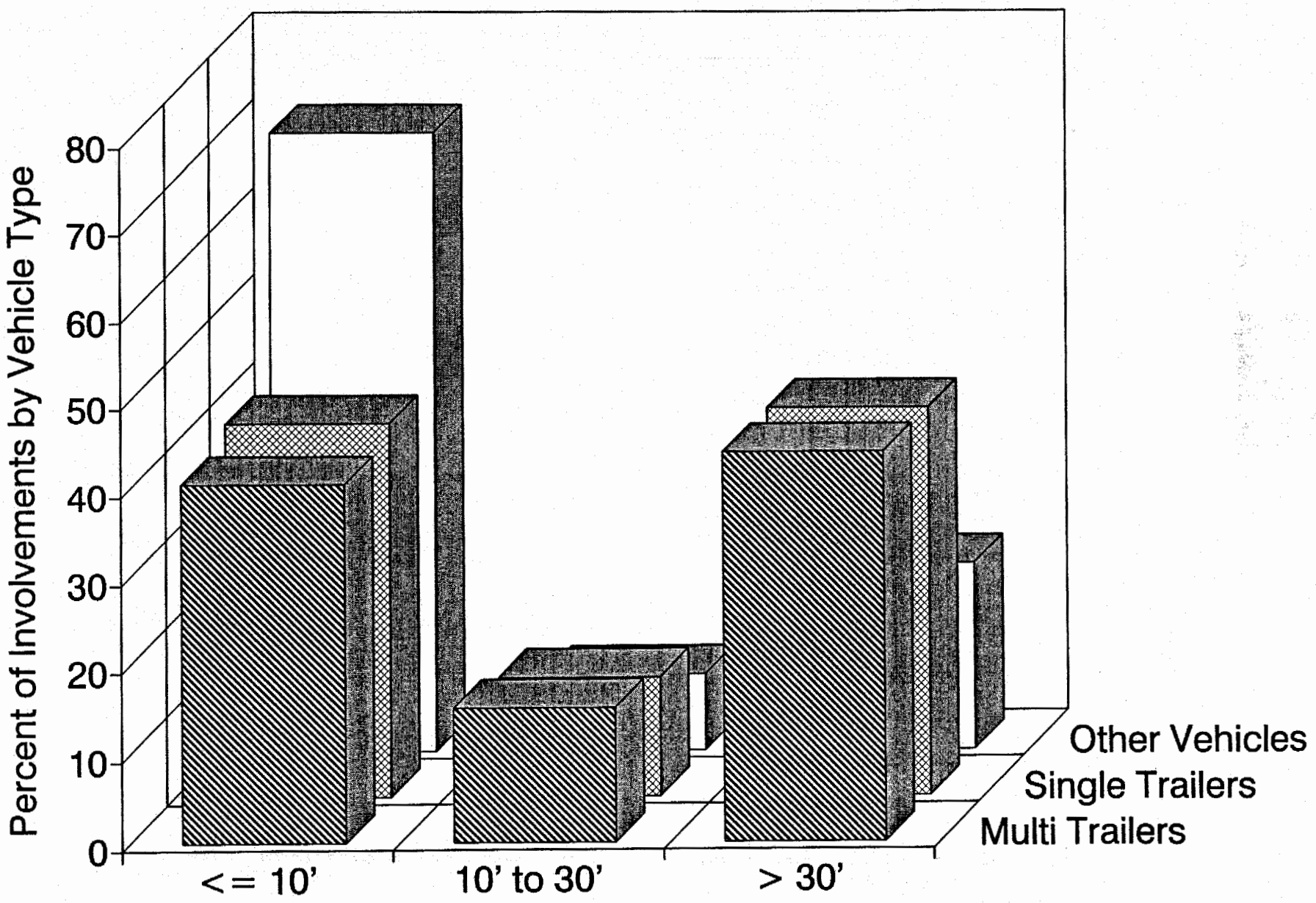
Involvements by Median Width
Percent of Involvements by Vehicle Type
80
70
60
50
40
30
20
10
0
<= 10'
10' to 30'
> 30'
Other Vehicles
Single Trailers
Multi Trailers

Figure 53

Involvements by Median Width

Rural Interstate

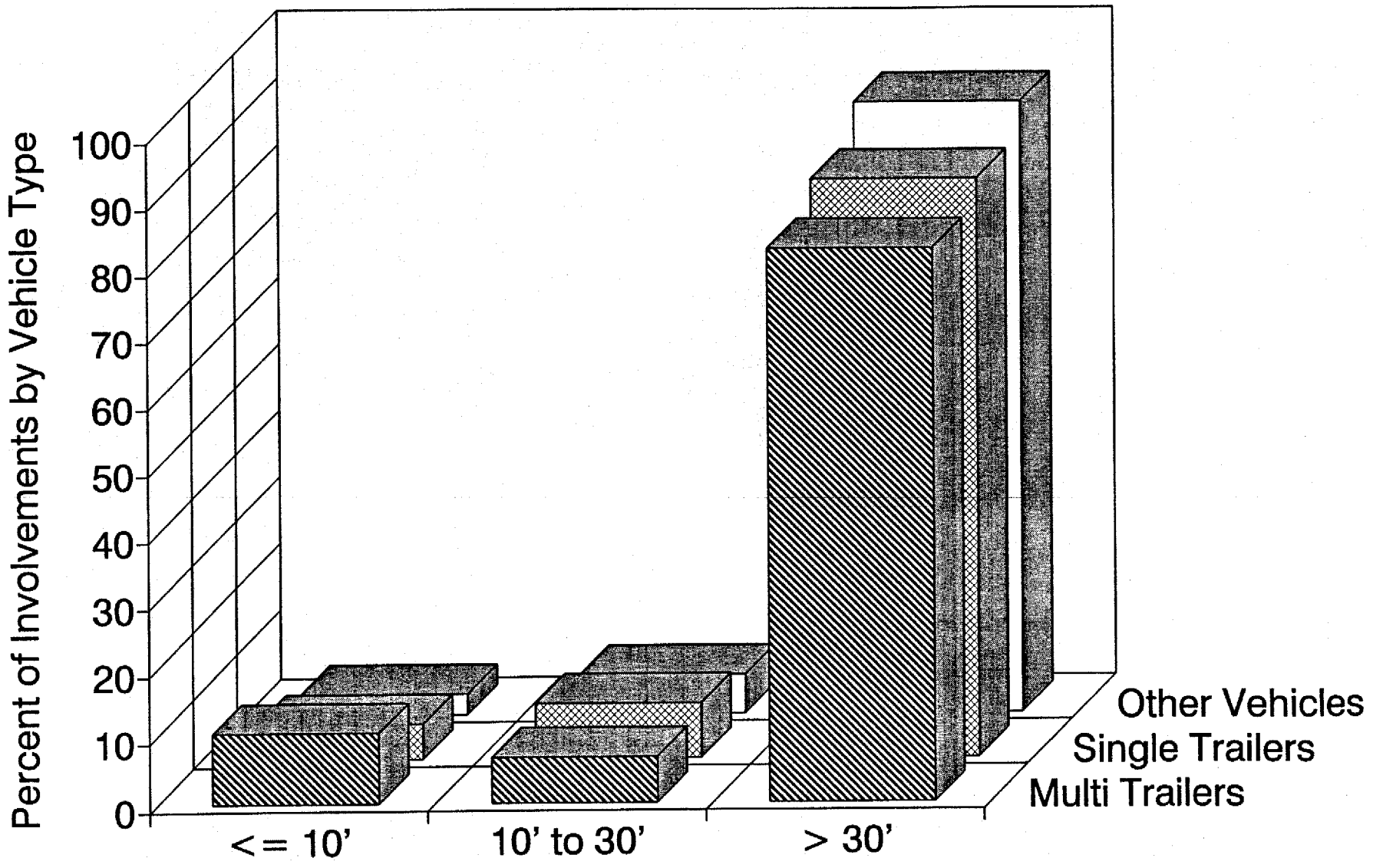

Figure 54

Involvements by Median Width

Rural Other

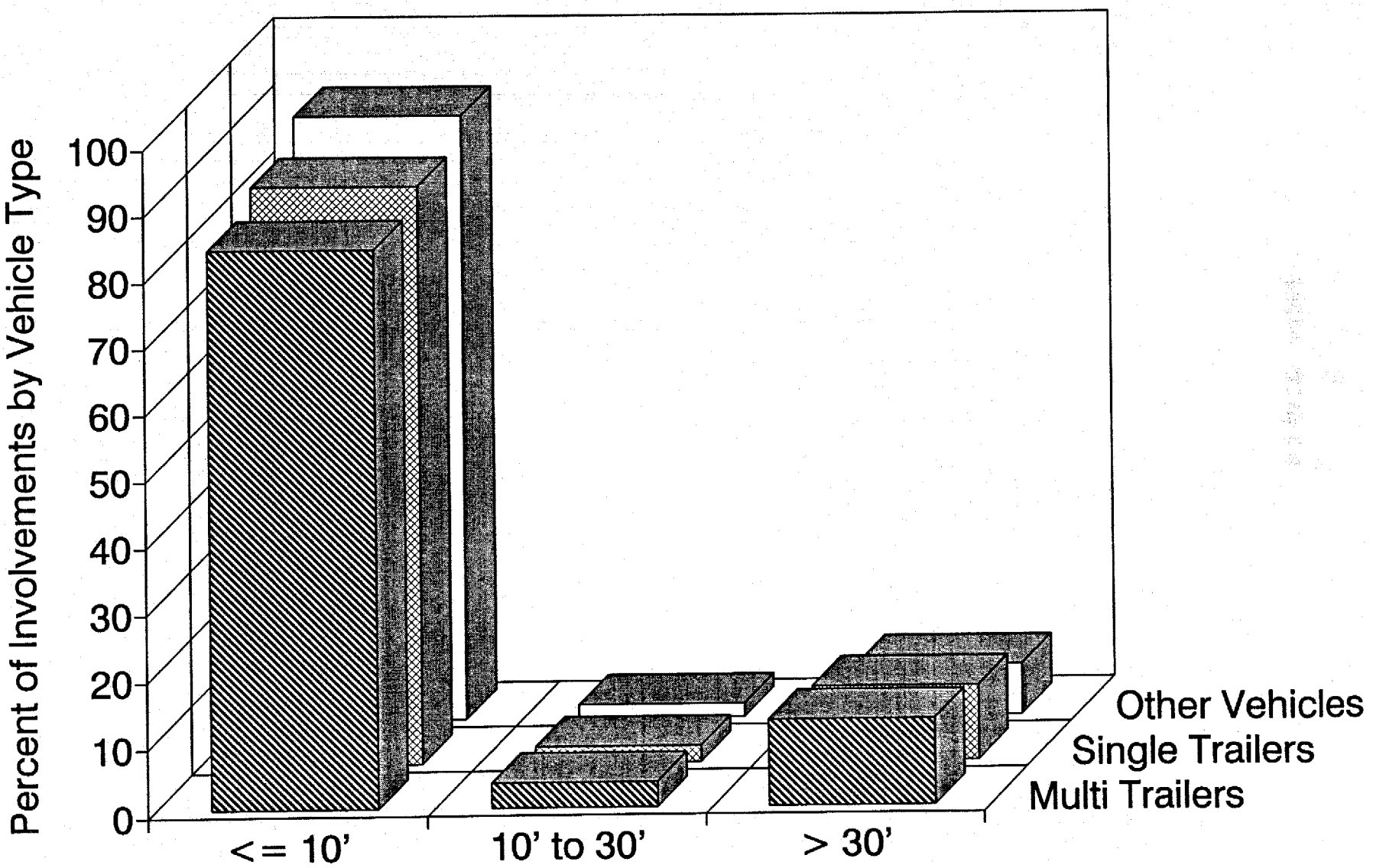

Figure 55

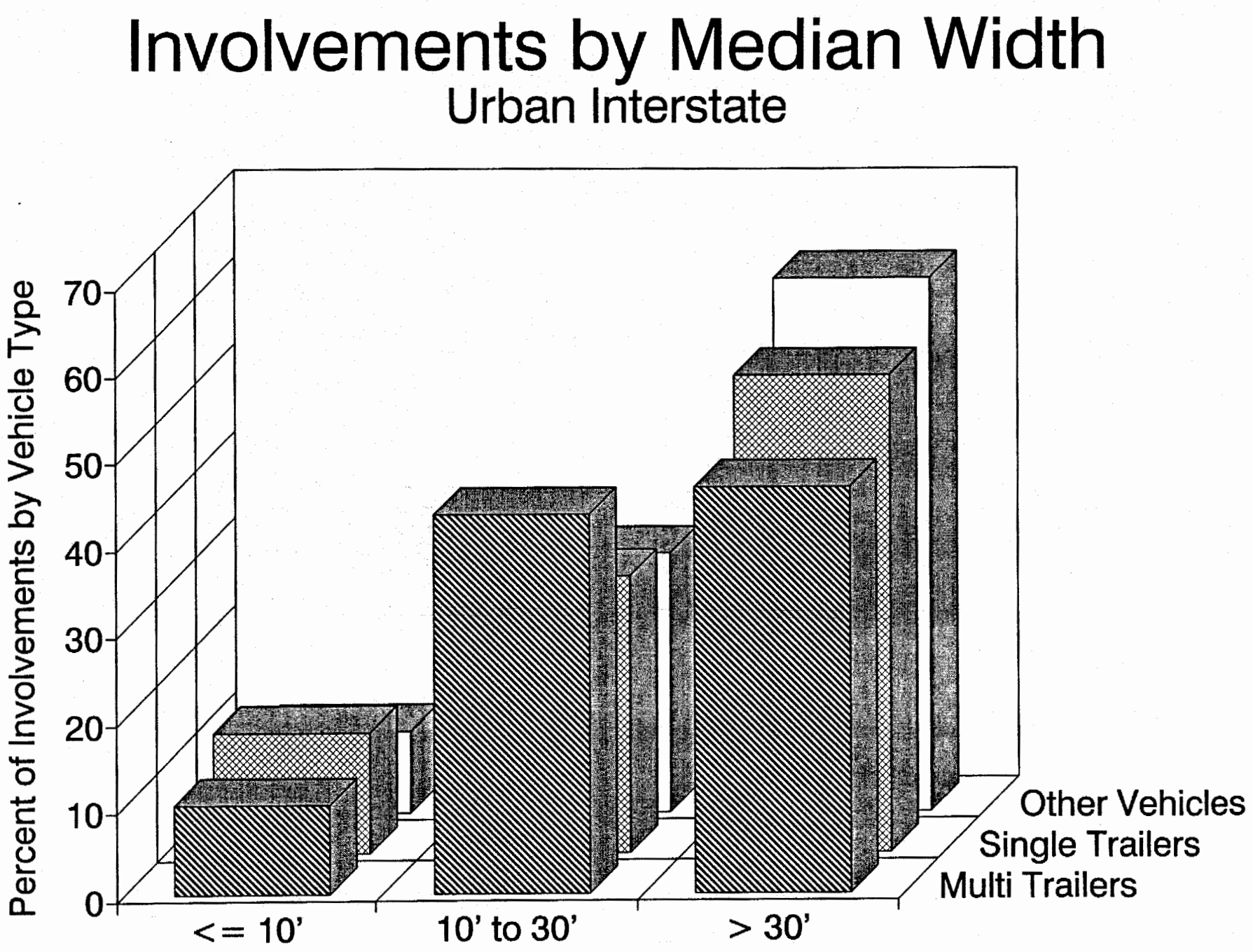
Involvements by Median Width
Urban Interstate
Percent of Involvements by Vehicle Type
70
60
50
40
30
20
10
0
<= 10'
10' to 30'
> 30'
Other Vehicles
Single Trailers
Multi Trailers

Figure 56

Involvements by Median Width

Urban Other

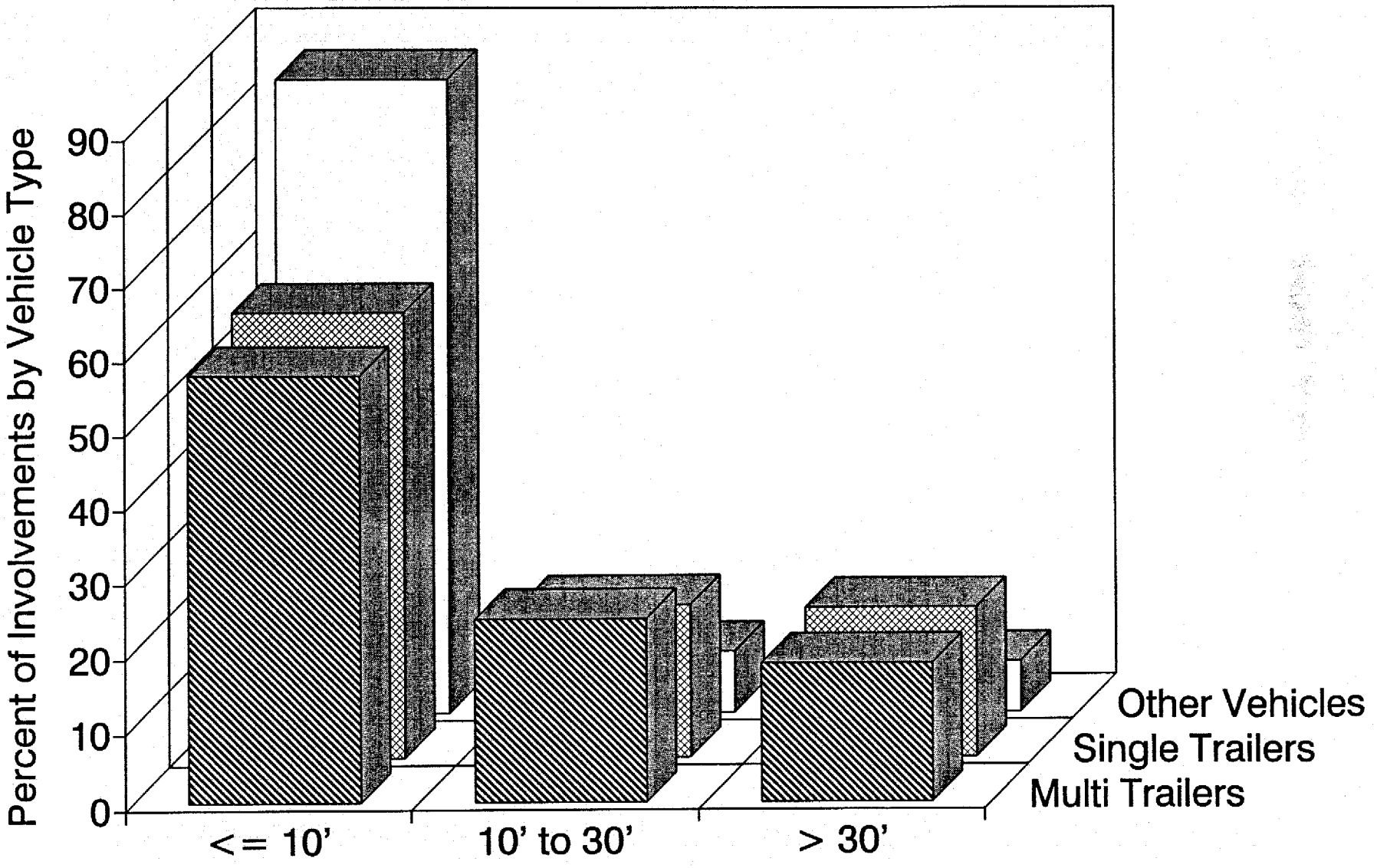

Figure 57

Involvements by Degree of Curve

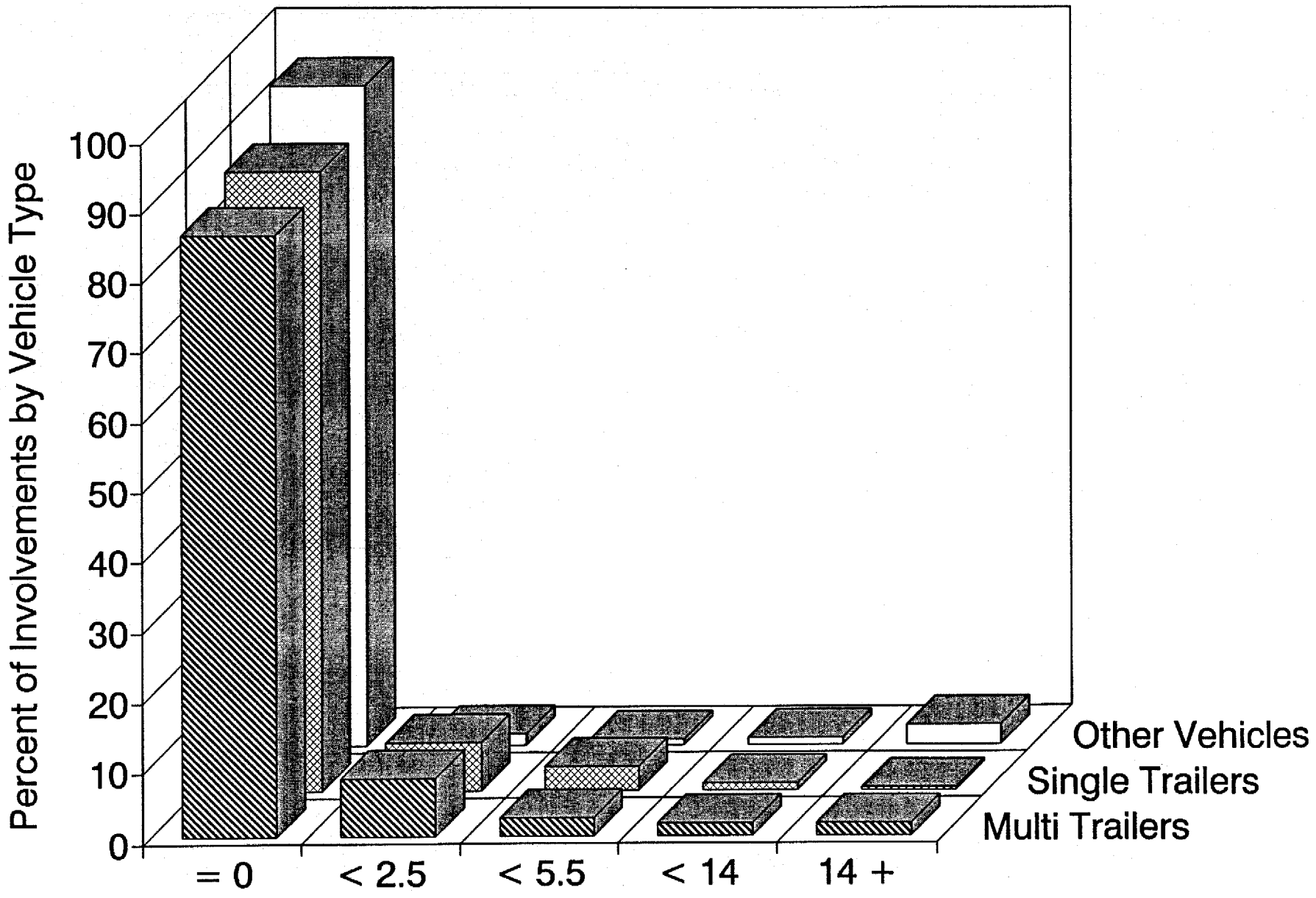

Figure 58

Involvements by Degree of Curve

Rural Interstate

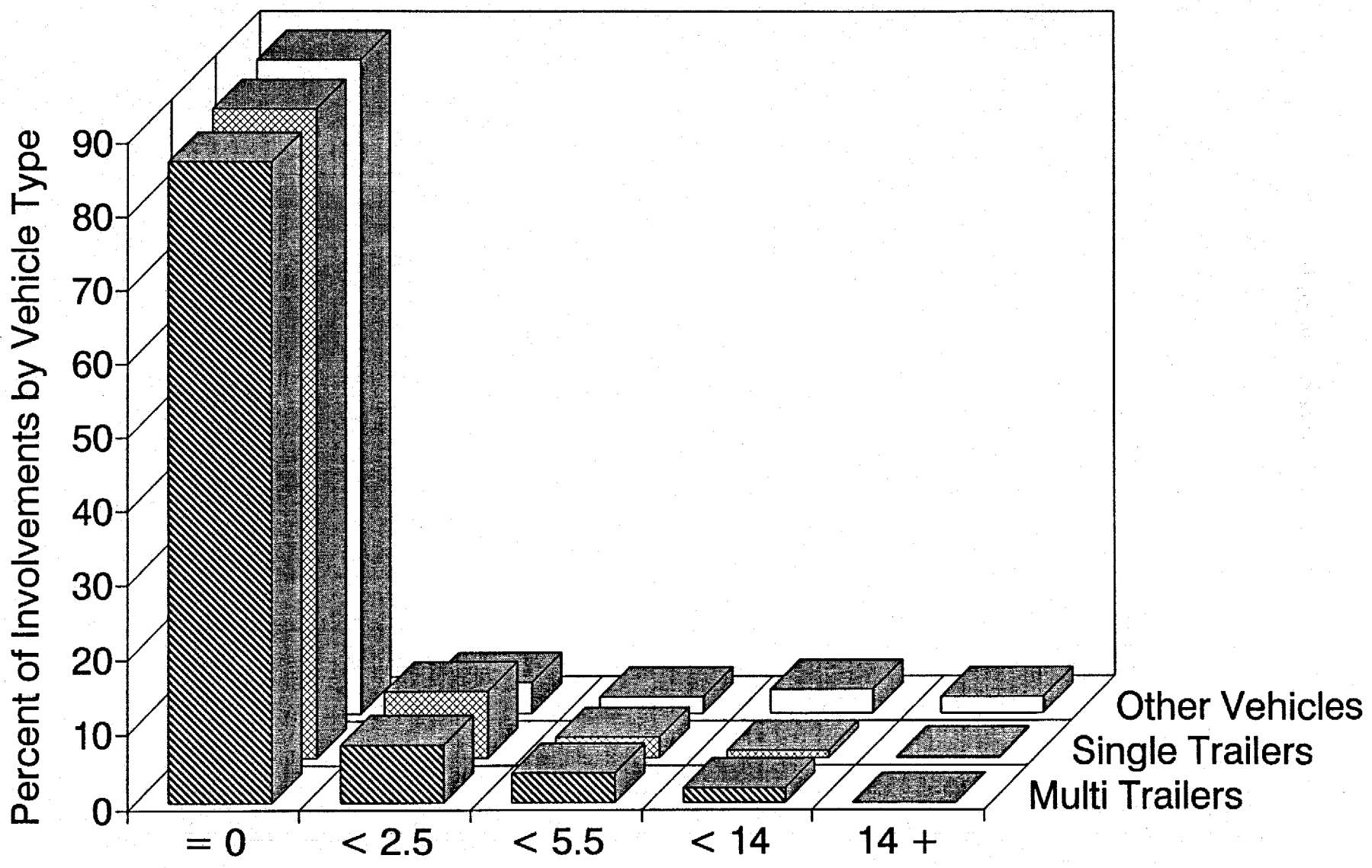

Figure 59

Involvements by Degree of Curve

Rural Other

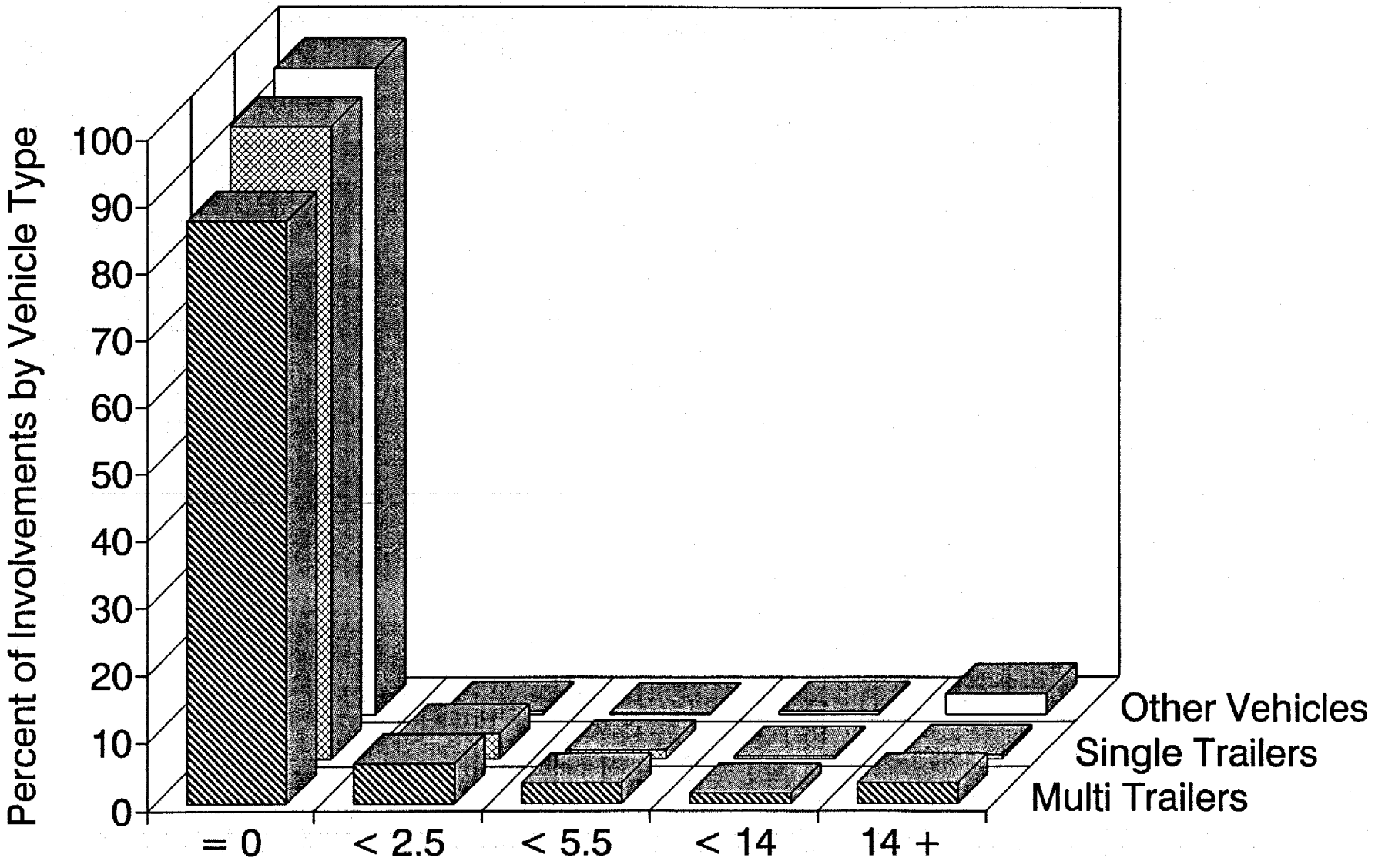

Figure 60

Involvements by Degree of Curve

Urban Interstate

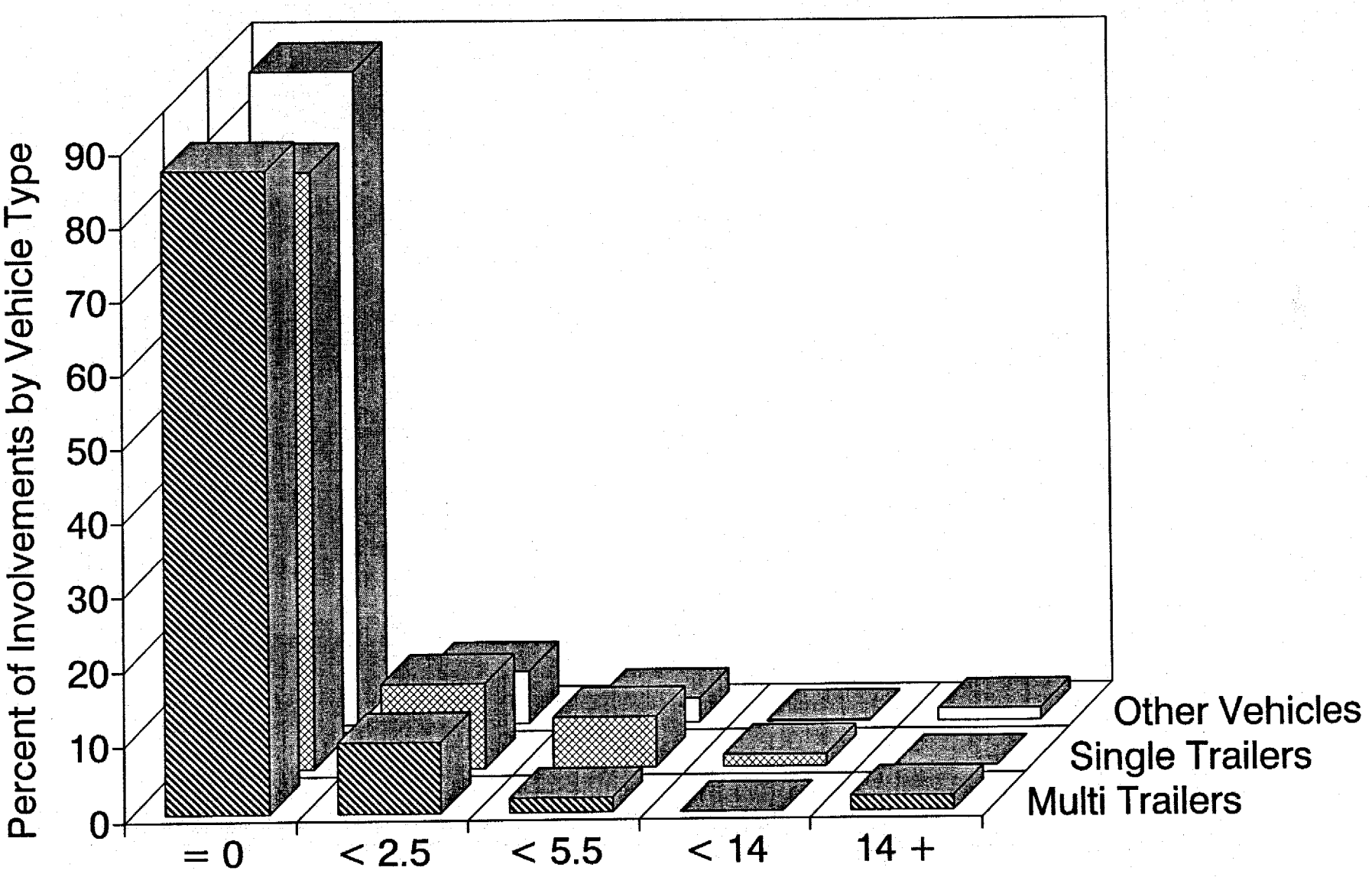

Figure 61

Involvements by Degree of Curve

Urban Other

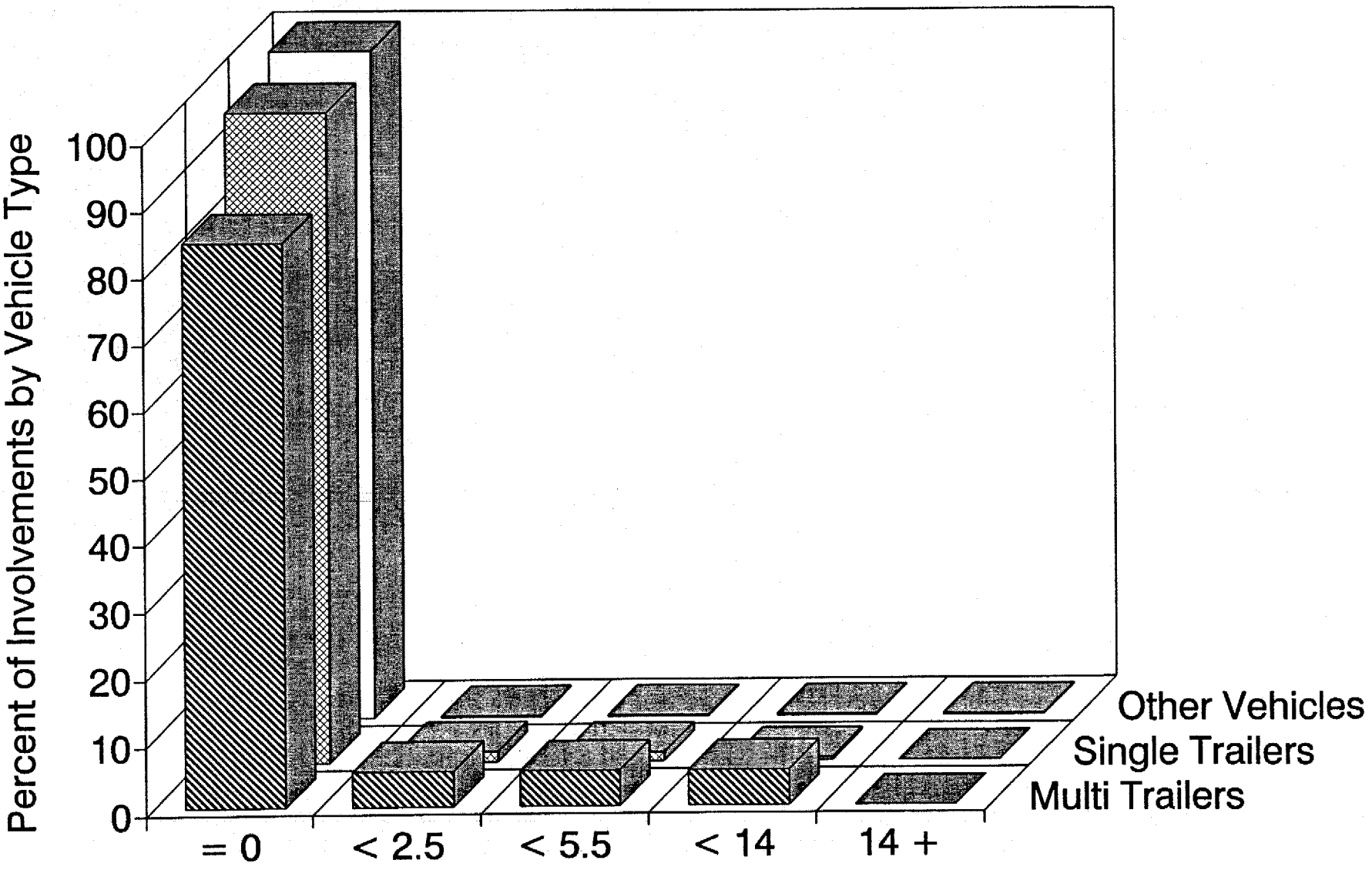

Figure 62

Involvements by Percent of Grade

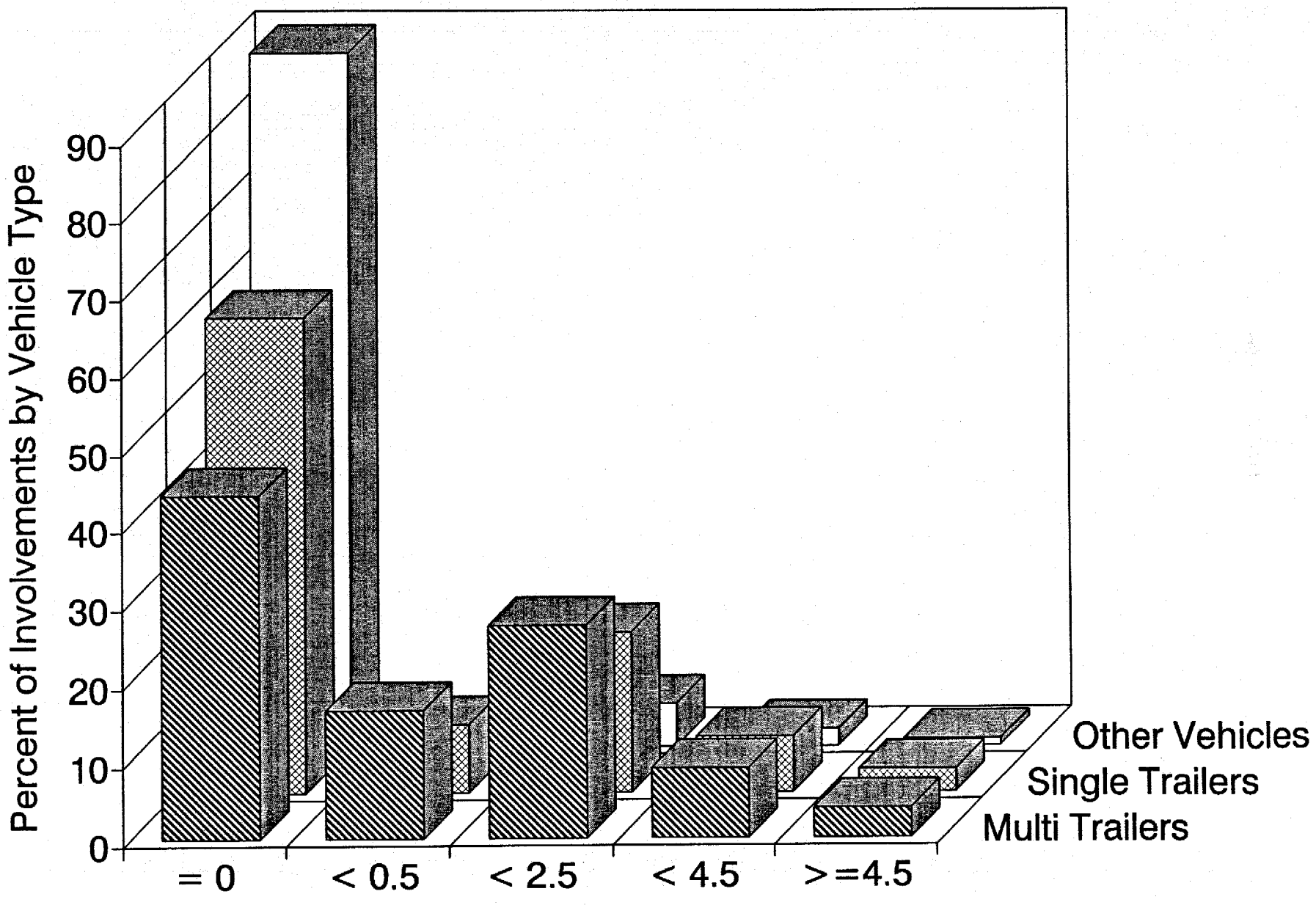

Figure 63

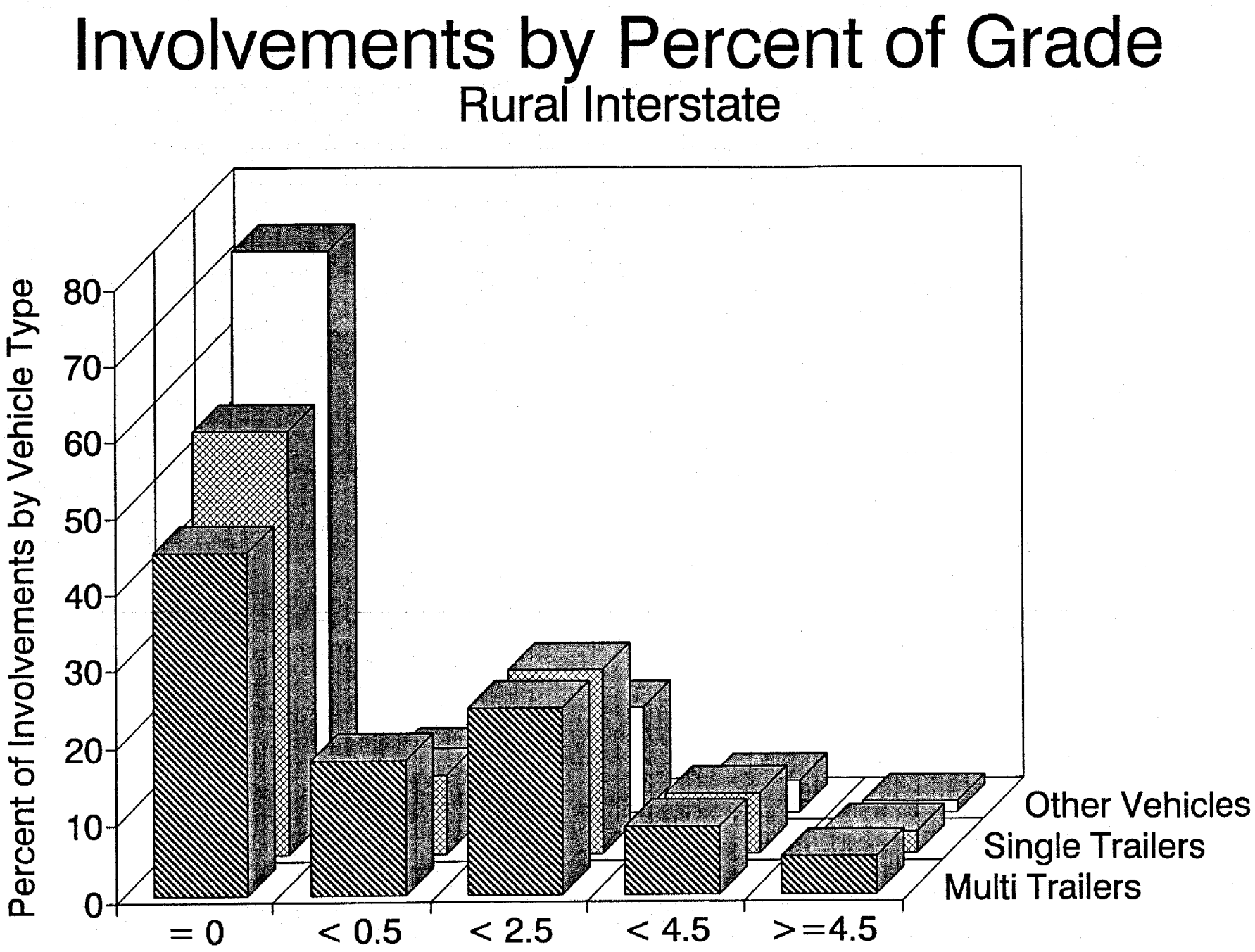
Involvements by Percent of Grade
Rural Interstate
Percent of Involvements by Vehicle Type
80
70
60
50
40
30
20
10
0
= 0
< 0.5
< 2.5
< 4.5
>=4.5
Other Vehicles
Single Trailers
Multi Trailers

Figure 64

Involvements by Percent of Grade

Rural Other

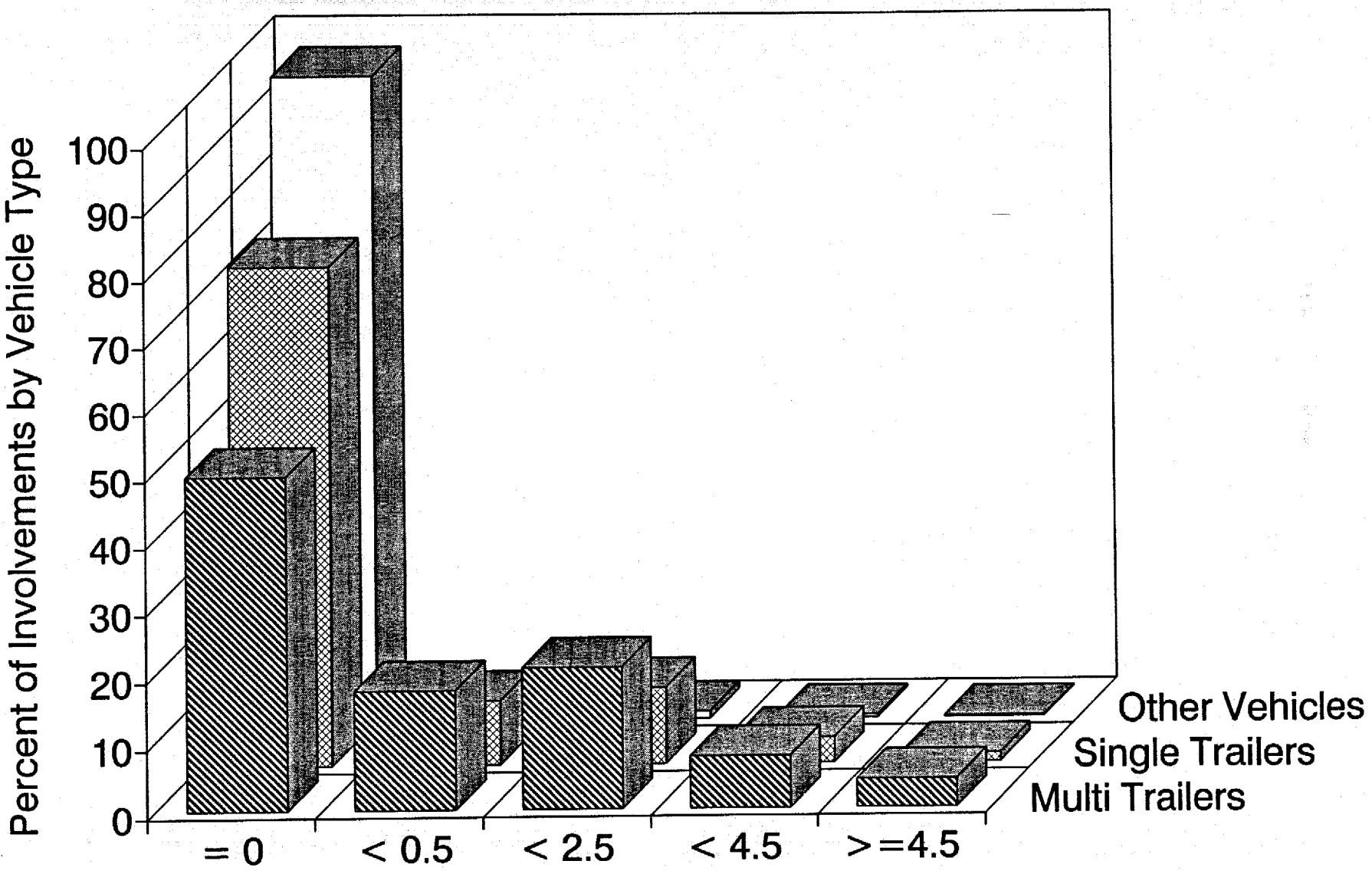

Figure 65

Involvements by Percent of Grade

Urban Interstate

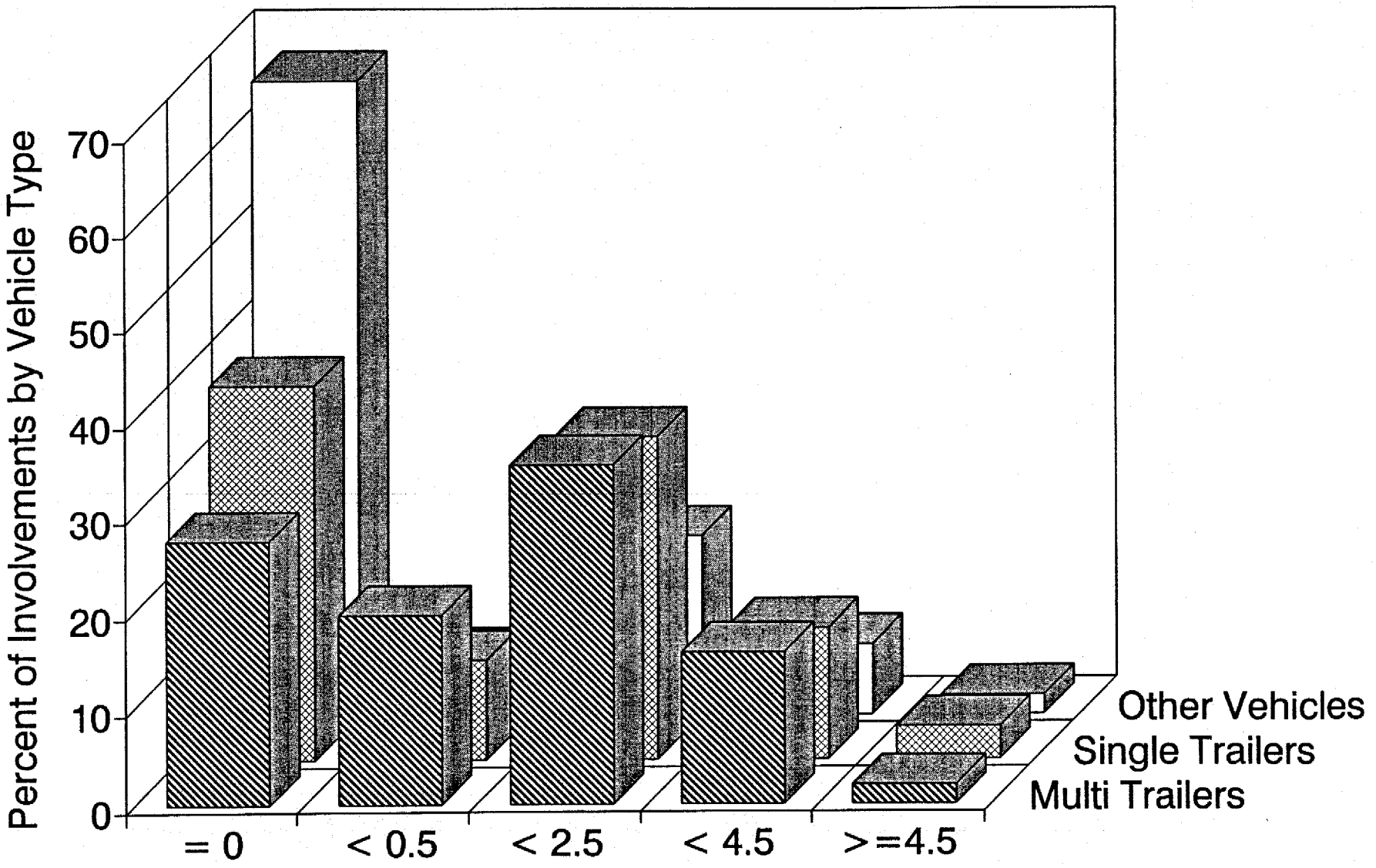

Figure 66

Involvements by Percent of Grade

Urban Other

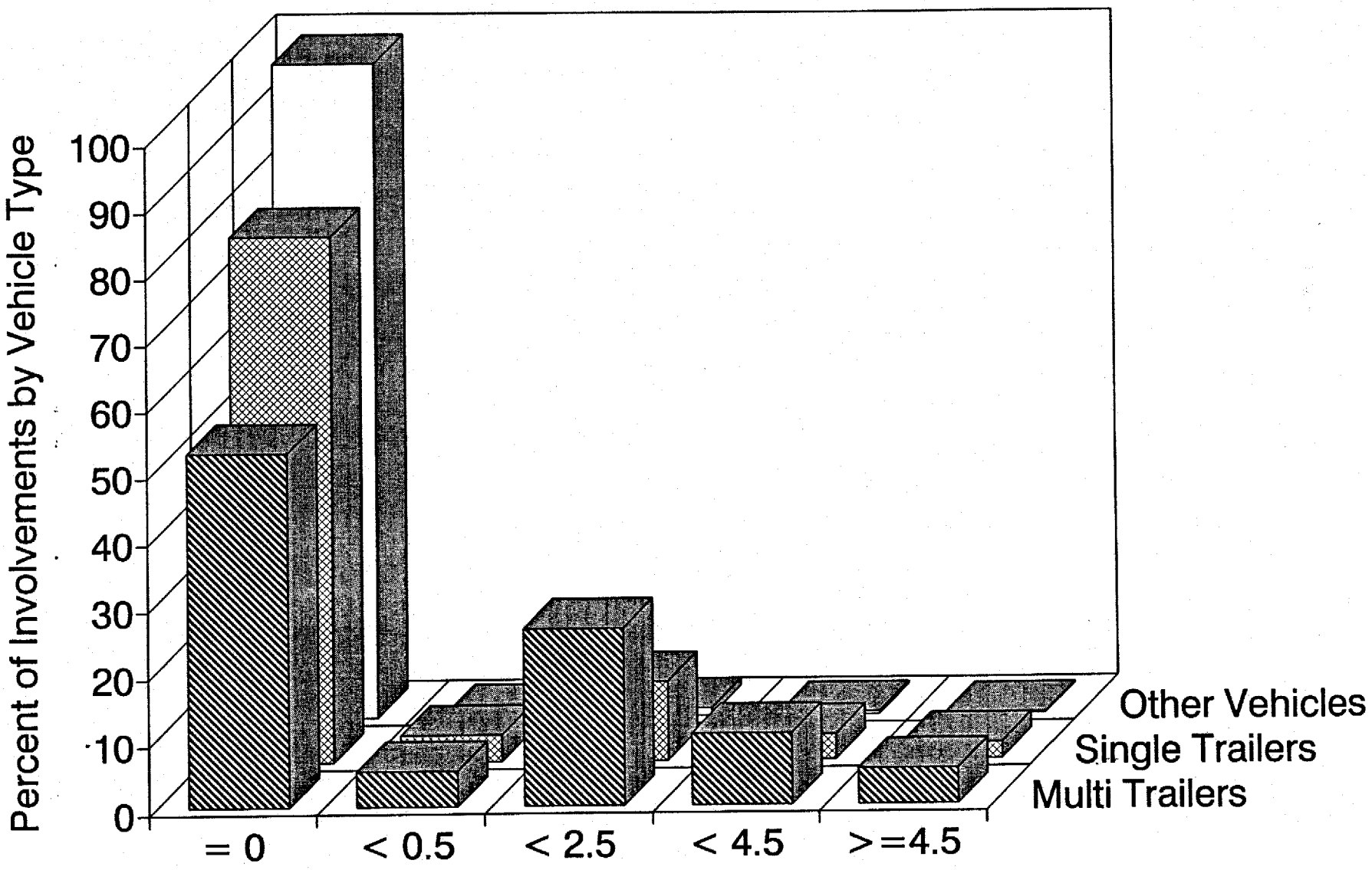

Figure 67

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