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DEVELOPMENT OF A COLLISION TYPOLOGY FOR EVALUATION OF COLLISION AVOIDANCE STRATEGIES*

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Abstract—This paper summarizes the results of an effort to identify and rank vehicle collision scenarios in order to create a "collision typology" that could aid in the assessment of the potential benefit of accident avoidance technologies. Data from four computerized accident files were used to construct an 18-level collision configuration variable. This variable includes the number of vehicles involved, their relative orientation, intent to turn, relation to intersection, and traffic control at the intersection. Distributions of the collision configuration variable were generated for several factors of interest using 1989 Michigan data. Five of the most prevalent collision types were selected for more detailed review based on the original police accident reports. The case studies lent additional insight into the circumstances of different accident types. Among other findings, the review suggested that in collisions at nonsignalized intersections, older drivers often stopped and then pulled out into oncoming traffic, while younger drivers more often failed to stop at all.

Collision avoidance and collision avoidance technologies are rapidly becoming a major focus of highway safety research. Since the mid-1960s, most of the effort in improving traffic safety by the motor vehicle industry, the federal government, and the research community has centered on occupant protection. Federal Motor Vehicle Safety Standards have led to marked improvements in vehicle design and structure, including increased integrity of the passenger compartment. Occupant protection, including both occupant restraint systems and improved interior design, as well as restraint usage laws, have contributed to steadily declining motor vehicle fatality rates based on miles traveled. However, there is a growing view that most of the readily available gains in occupant protection have been realized and that further progress will be slower and more costly (Viano 1988).

The recent programs to design and implement Intelligent Vehicle Highway Systems (IVHS) have focused attention on the opportunities created by advanced technology to address collision avoidance. IVHS holds the promise of smoother, more efficient traffic flow through the application of advanced technology to help a driver avoid traffic congestion, plot the most efficient route to a destination, and optimize speed controls. The increased information about the traffic environment and the flexible, automated vehicle control that IVHS envisions will also allow a new approach to traffic safety. In this approach, the focus shifts from protecting occupants in the event of a collision to designing automated controls and warnings that may help drivers avoid a collision in the first place.

However, the safe and effective application of advanced technologies to the problem of collision avoidance first requires an understanding of the traffic situations in which collisions occur. Finklestein (1989) suggests that sufficient data exist in national databases like NASS (National Accident Sampling System) and FARS (Fatal Accident Reporting System) and in state collision files to be able to describe the relative importance of various factors that contribute to accidents. The challenge is to find the best methods for analyzing these data and for determining priorities in developing collision avoidance countermeasures. Accordingly, the goal of the present research project was to identify and rank collision scenarios, using existing data, in order to create a "collision typology" that would be helpful in considering collision avoidance devices.

LITERATURE REVIEW

A review of literature relevant to collision categorization found relatively little work done to develop collision typologies. Some have categorized factors contributing to accidents into three categories: human, environment, and vehicle. However, human error is implicated in 88%–95% of the collisions in these studies (Sabey and Taylor 1980; Treat et al.

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1979; Perchonok 1972). This approach ignores the problems associated with classifying collisions and their related causes (human or otherwise). The idea of human culpability is attractive, but it fails to address the issue of helping the driver to avoid the collision.

It is increasingly clear that precrash movements and intents of the involved vehicles (driver at fault or not) are of primary interest in thinking about collision avoidance technologies. This idea has already been proposed by traffic safety experts (Haight et al. 1976). Attempts to follow the precollision movements of vehicles have been both narrow and broad. Fontaine, Malaterre, and Van Elslande (1989) separated 350 accidents into six categories based on rural/urban, intersection involvement, number of vehicles, and time of day. They found that 56% of the collisions involved an urban intersection, while only 9% were single-vehicle, rural, nighttime accidents. They estimated that 29.5% (183/621) of the drivers could have benefited from one of 14 collision warning devices suggested in the report. However, the authors' confidence in the application of their results to larger databases was low. On a larger scale, Joksch (1983) discusses practical considerations for collecting, classifying, and analyzing accident data. While not providing actual data, he develops a framework for categorizing collision data into six large groups, each with five or more subgroups, based on number of vehicles and vehicle movement and direction.

The only complete taxonomy of collision types came from the well-known study of accident causation by the Indiana University Institute for Research in Public Safety (Treat et al. 1979). This report included an elaborate "driver situation taxonomy," consisting of 4 major categories, 29 secondary categories, and an additional 61 subcategories to classify 613 vehicles involved in 372 collisions that were studied in detail in the early 1970s. Accidents on freeways and collisions involving heavy trucks or motorcycles were excluded, as were most pedestrian and bicyclist collisions. The classification system focused on the precrash movements of the involved vehicles, whether these were at an intersection, whether one or more vehicles were in the accident, and whether there was a conflict with another vehicle (not explained). Seven out of 10 of the accidents involved an "emergency conflict situation." The researchers estimated that if the drivers who had time to do so had carried out the most appropriate evasive action, almost half of these conflict collisions would certainly or probably have been avoided.

The use of a well-defined collision typology allows the identification of countermeasures and their effectiveness. Tumbas et al. (1977) carried out a special analysis of 215 Indiana accidents in order to assess the collision avoidance or mitigation potential of radar warning, radar-actuated brakes, and antilock brakes. They estimated that a combination of radar warning (noncooperative—i.e. not requiring reflectors on other vehicles or roadside objects), radar-actuated brakes, and four-wheel, antilock brakes could have had a beneficial effect in 38% of these collisions.

A PRELIMINARY COLLISION TYPOLOGY

Creating a collision typology appropriate to the issue of collision avoidance is a challenging process. Collisions can be classified in innumerable ways, depending on the research problem at hand. Moreover, as the literature review indicated, there has been relatively little work in developing collision typologies. In this sense, the procedure discussed here was exploratory, and the resulting typology should be considered an initial attempt that should be repeated.

Given a focus on collision avoidance, the process of constructing a typology must begin with a hypothesis about the characteristics of accidents that will best discriminate the opportunities for intervention. This necessarily involves some assumptions about the types of intervention, or technologies under consideration. This project emphasized vehicle-based collision avoidance technologies. Consequently, the investigators assumed that the precollision relative position of the vehicles is of primary importance.

Prevalence and risk

Another issue in developing the typology was the choice of a dependent variable. Two obvious candidates are the prevalence and risk of a given type of accident (Campbell et al. 1988). Prevalence is simply the proportion of collisions involving a particular factor. Countermeasures aimed at a factor associated with a large proportion of accidents have greater potential benefit than those aimed at something that occurs very infrequently. Risk is the likelihood of experiencing a collision involving a particular factor per unit of exposure to that factor. It seems appropriate that countermeasures for high-risk factors should take priority over those for low-risk factors, particularly if they are equally prevalent.

While data exist for estimating the prevalence of particular collision types, there are no satisfactory sources of exposure data or even a consensus of how best to measure exposure. Vehicle-miles of travel is a common measure of exposure, but total travel is not sufficient because of the different levels of risk associated with particular factors. For example, nighttime travel generally has a higher risk than daytime travel. Exposure to many types of collisions increases as a vehicle enters an intersection and performs a certain maneuver (Joksch and Knoop 1983); thus travel on nonintersection road segments has a different risk level than travel through intersections. Defining exposure as "the opportunity to be involved in an accident," Council, Stewart, and Hodgeman (1987) argue that exposure types parallel collision types, so individual, specific exposure formulas should be calculated separately for each collision type of interest. Haight (1973) describes the method of "induced exposure" as a means of bypassing the need for travel data. In this method, the proportion of "not-responsible" drivers in two-vehicle collisions in a particular category (defined by vehicle, driver, and environmental characteristics) is equated with the relative exposure of that category. This method has the advantage of requiring only accident data, but possesses drawbacks, including the difficult and/or subjective nature of identifying the "not-responsible" subset.

Therefore, assuming mileage is the desirable exposure measure, one ideally would wish to have travel data cross-classified by the factors that distinguish the differing risks for different types of travel. Since there are currently no available databases that contain all of these factors, collision types in this paper will be considered according to prevalence but not risk. The analysis also will consider the severity of different collision types. Preventing a collision that typically results in serious or fatal injury is of greater benefit than preventing a collision with less severe consequences.

Accident data sources

The research team used four different files of accident data in attempting to develop a typology of the most common motor-vehicle collision situations. Two were state files consisting of all police-reported accidents in Michigan and Washington. The project used the 1989 version of the Michigan accident database, which contained 417,252 accident records and 707,718 traffic unit records (motor vehicles, pedestrians, pedalcyclists). Because this file was so large, a 50% random sample was conducted at the accident level, pulling all corresponding vehicle records. This resulted in an analysis file with information on 208,399 accidents involving 353,372 traffic units. The full version of the 1988 Washington file was used. This database contained 125,920 accident records and 237,019 vehicle records.

The third source of accident data was the 1985 and 1986 NASS files. These are produced by the National Highway Traffic Safety Administration (NHTSA), as part of a program begun in 1980 for carrying out special investigations on a nationally representative sample of police-reported accidents in the various states. This is the only nationally representative database covering all types of motor vehicle accidents in the United States. However, it is by necessity rather limited in size. Consequently, the project combined two years of data to create a file of 23,371 accidents involving 38,482 vehicles. Weighted totals from NASS were used in the analyses.

The final source of data was the Crash Avoidance Research Data file, commonly known as the CARDfile. This database is the product of a recently established NHTSA project to combine all police-reported accidents for three years from six states in a common format in order to have available a large accident database. The six states are Indiana, Maryland, Michigan, Pennsylvania, Texas, and Washington, and the three years used were 1984, 1985, and 1986. Since the original CARDfile contained over 4 million accidents and over 7 million vehicles, a special 5% random-sample file was drawn for the actual analysis. This file contained 211,943 accident records and 370,151 vehicle records.

Constructing the typology

Creating the collision typology was an iterative process. The first step involved reviewing the many variables in the data files and choosing the ones that appeared most useful for the task of developing a typology of the most common collision scenarios. The research team combined certain variables into a collision configuration variable and selected certain others for use as control variables.* The control variables were chosen based on previous research that had shown them to either be important in determining the probability of an accident (e.g. light condition, road class) or to be useful in identifying very different accident subsets (such as casualty versus noninjury accidents).

The hope was to construct a typology appropriate for evaluating vehicle-based collision avoidance technology. The primary input for these devices was assumed to come from sensors mounted on the vehicles. With these assumptions, the relative position and movement of the vehicles just prior to the collision seemed to be of key relevance. Thus, one premise followed in creating the collision configuration variable was that it was more appropriate to look at the intended precrash movements of the involved vehicles than whether the resulting collision configuration was angle, head-on, rear-end, etc. Once the research team made initial decisions about classifying collisions and control variables, computer runs were

*A *control variable* is one whose influence is "controlled for" by analyzing the cases for each of its levels. For example, when distributions are shown for each level of road class, the effects of the different levels of road class are said to be controlled for.

made on each of the four datafiles. After reviewing the resulting set of tables, the research team made modifications to the collision classification scheme, adding certain variables and deleting others, and then ran another set of tables. This process was repeated until the form of the collision typology discussed in this paper was produced.

Certain restrictions were made in the collision data for this project. The main focus was the accident experience of "ordinary" drivers. Consequently, accidents involving drivers who had been drinking, drivers who were indicated to have been driving recklessly or carelessly, and drivers under the age of 16 were excluded from the analyses. The exception was that reckless drivers cannot be identified in the Washington or CARDfile data, so accidents involving reckless drivers were not excluded from those two files. Since the project concerns the accident experience of motor vehicles, collisions involving pedestrians or pedalcyclists were excluded as well.

The unit of analysis was a vehicle *involvement*, not an accident. Each data record concerned the accident experience of just one vehicle. Thus, one accident could be tallied in the data multiple times, once for each vehicle involved in the collision. Consequently, percentages relating to single-vehicle accidents are less than half what they would be if the analyses had been conducted at the accident level.

The final collision typology generated has 18 levels and incorporates the number of vehicles involved in the accident, the relation of the accident to an intersection or driveway, the relative precrash orientation of the vehicles, their intent to turn, and the traffic control in the case of accidents taking place at an intersection. The typology is diagrammed in Fig. 1. The first split of the data was made according to whether the vehicle was involved in a single-vehicle or a multivehicle accident. These two groups were then divided based on whether the accident took place at an intersection. Single-vehicle involvements at intersections were split according to traffic control. Signalized intersections have an automated three-color traffic light, while signed intersections are controlled by a stop or yield sign or a flashing light. Single-vehicle nonintersection involvements formed their own category.

Multivehicle intersection involvements were split into three broad categories: vehicles approaching on crossing paths prior to the accident, vehicles proceeding from the same direction, and vehicles approaching from opposite directions. Each of these three groups was split according to whether all vehicles in the accident were moving straight ahead prior to the collision, or at least one was attempting a turn. The resulting six groups were next split according to traffic control at the intersection, forming 12 end categories. Finally, multivehicle involvements occurring away from intersections were split into three categories. The "driveway" group represents accidents that occurred when one or more vehicles was entering or leaving a driveway or parking space. The other two groups represent vehicles that were either approaching in the same direction, or from opposite directions, just prior to the accident.

Distributions based on the collision typology

A comparison of the 18-level collision typology among the four accident datafiles is shown in Table 1 and Fig. 2. For this table and figure, the data have been restricted to passenger cars only where driver age was known. Cases that could not be classified as one of the 18 categories, primarily because of missing data on one of the key variables, have also been excluded. The various restrictions in the data sharply reduced the number of cases available for analysis in each file. For example, in the Michigan data, the original 353,372 traffic units were reduced to 315,343 after restricting the data to accidents involving only "ordinary" drivers and no pedestrians or pedalcyclists. Focusing only on passenger cars reduced the number to 247,052, removing cases with unknown driver age to 232,420 and omitting other or unknown collision types to 227,128.

Despite the reduction in number of cases, the sample sizes of all the files except NASS remain robust (Table 1). For the other files, the sample sizes are so large that almost any difference between categories is expected to be statistically significant. As Table 1 and Fig. 2 indicate, the collision typology distributions are quite stable across the four datasets. Considering the somewhat disparate data collection and coding methods in the four data sources, the consistency between files is encouraging. The results indicate that some of the more common collision categories are single-vehicle nonintersection accidents; multivehicle driveway/parking involvements; multivehicle, nonintersection, same direction collisions; and the group of multivehicle, crossing paths at intersection accidents.

To learn more about the collision categories, the research team examined distributions of the collision configuration variable across the levels of particular control variables. Given the similarity of the overall collision typology distribution among the four datafiles, the investigators decided to use just one file for the additional distributions. The CARDfile was rejected because it contains no road class variable and has an unacceptably high missing data rate on its rural/urban variable. Concerns with sample size prevented use of the NASS files. This left the two state

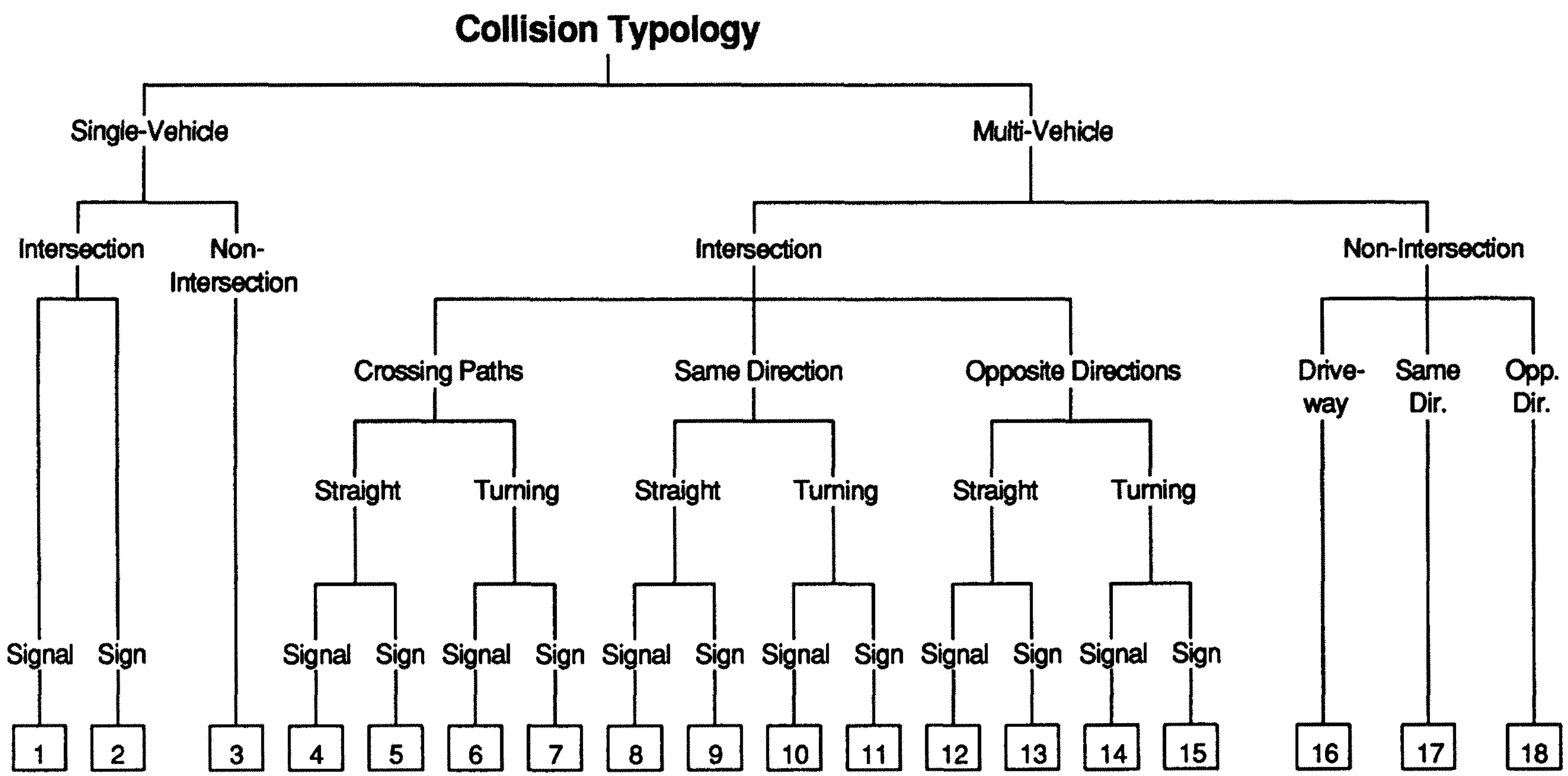

Fig. 1. Hierarchical diagram of collision typology.

Table 1. Collision type distributions for four datafiles

Collision type	Washington 1988	Michigan 1989	NASS 1985–1986	CARDfile 1984–1986
S.V. Intersection/Signal	0.19	0.24	0.37	0.39
S.V. Intersection/Sign	1.56	2.12	1.54	2.91
S.V. Nonintersection	9.10	15.27	13.03	14.55
M.V. Cross/Straight/Signal	5.62	4.21	4.90	6.55
M.V. Cross/Straight/Sign	16.73	7.86	8.62	11.73
M.V. Cross/Turning/Signal	0.68	1.48	1.47	1.65
M.V. Cross/Turning/Sign	1.44	4.58	4.75	5.56
M.V. Same Dir/Straight Signal	7.62	7.23	8.25	5.82
M.V. Same Dir/Straight/Sign	9.90	8.75	6.95	6.04
M.V. Same Dir/Turning/Signal	1.33	1.05	0.60	1.13
M.V. Same Dir/Turning/Sign	2.02	2.43	0.92	3.24
M.V. Opp Dir/Straight/Signal	0.13	0.17	0.34	0.25
M.V. Opp Dir/Straight/Sign	0.55	0.67	0.71	0.95
M.V. Opp Dir/Turning/Signal	4.69	4.24	4.93	5.18
M.V. Opp Dir/Turning/Sign	3.07	2.22	2.16	3.59
M.V. Noninter/Driveway	14.59	15.03	16.97	11.03
M.V. Noninter/Same Dir	18.32	19.92	19.34	14.99
M.V. Noninter/Opp Dir	2.47	2.53	4.14	4.41
Total	100.00	100.00	100.00	100.00
Sample Size	118,908	227,128	17,419	164,375
Sample Fraction (%)	100	50	—	5

Note: The figures in this table are column percentages for each datafile at the vehicle level. They represent passenger cars only and exclude cases where driver age was unknown. Only non-pedestrian/pedalcyclist collisions with "ordinary" drivers were considered.

files of Michigan and Washington. Since the 50% Michigan sample file contains more cases than the entire Washington file, the 1989 Michigan file was selected for the series of two-way distributions. The Michigan file contains all of the variables required for this series of distributions.

The size of the Michigan file should ensure that most of the observed results are significant with respect to the Michigan accident experience. The results cannot be generalized to the U.S. accident experience, since no state is representative of the nation in terms of all relevant factors such as climate, demographics, accident reporting threshold, and composition of the motor vehicle population. However, while absolute percentages would undoubtedly change if the analyses were repeated on national data, most of the *relative* differences between collision types would be expected to be preserved. This expectation is supported by the consistency in the overall collision typology distributions among the four data files.

In each set of distributions that will be considered, cases that could not be classified as one of the 18 collision types have been excluded. Each set of analyses was also confined to the levels of the particular control variable described. For example, a case with missing data on road surface condition will not appear in the road surface condition set of distributions. However, if the same case was coded for driver age, it will appear under the appropriate level of the driver age set of distributions.

Vehicle type. In Fig. 3, the collision type distribution is compared for passenger cars, light trucks and vans, and medium and heavy trucks in the 50% Michigan 1989 file. One main difference between the three vehicle types is that while 25% of the light trucks were involved in single-vehicle, non-intersection accidents, this was true of only about 15% of the passenger car and large truck involvements. Large trucks had a higher proportion of multivehicle, non-intersection, same direction involvements (29%) compared to cars (20%) and light trucks (18%). More minor differences include the relatively low incidence of driveway/parking accidents for large trucks and the higher incidence of multivehicle, same direction, turning collisions among large trucks. On the other hand, passenger cars were overrepresented in the multivehicle, opposite direction, turning accidents.

One factor that is certainly involved in the differences between the distributions is the travel patterns of the different vehicle types. For example, large trucks typically have a higher share of travel on limited access roads in rural areas than do other classes of vehicles. This affects the likelihood of large trucks experiencing particular types of collisions and is probably responsible for their lower incidence of

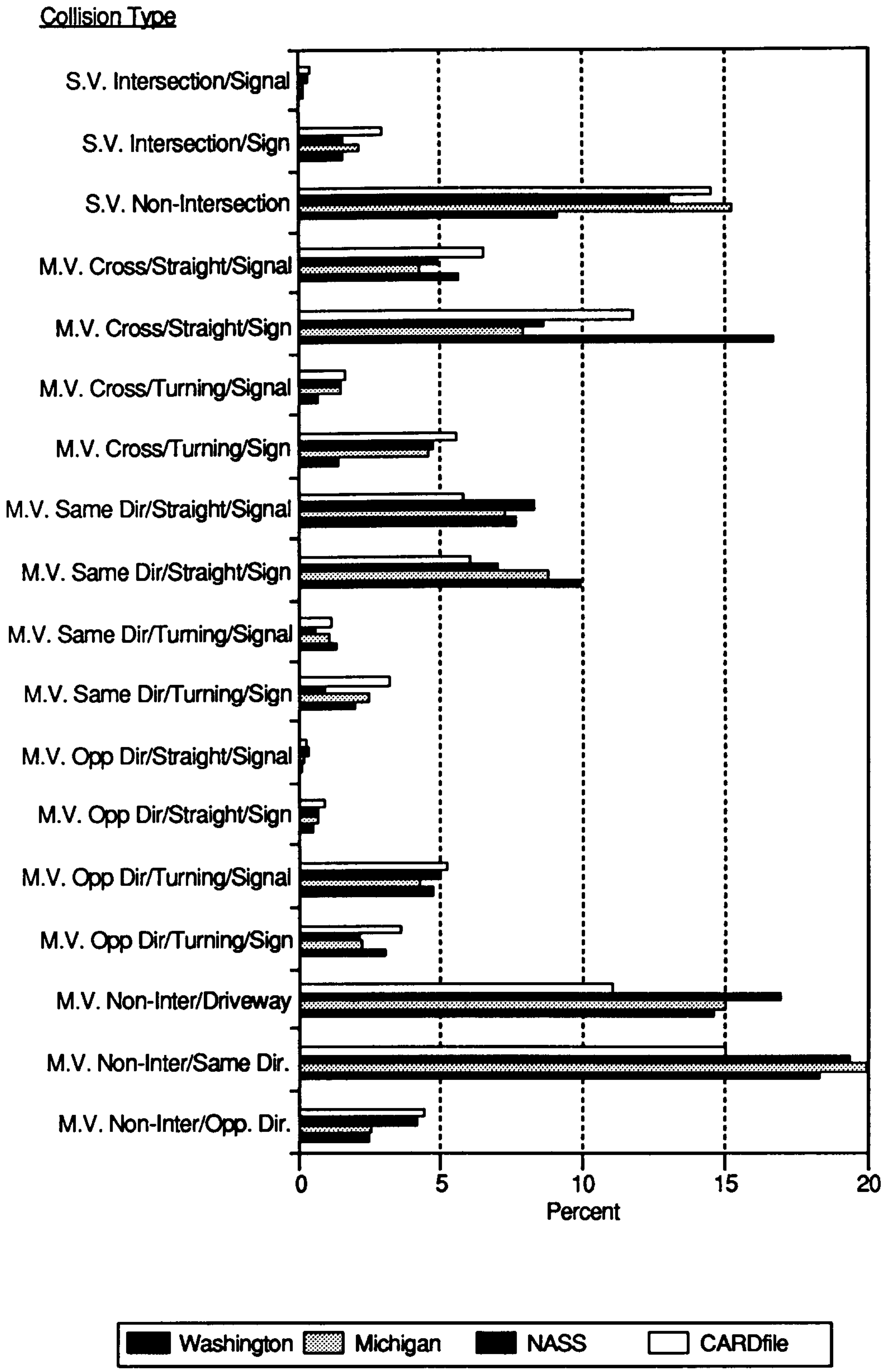

Fig. 2. Collision type distribution, comparison of four datafiles.

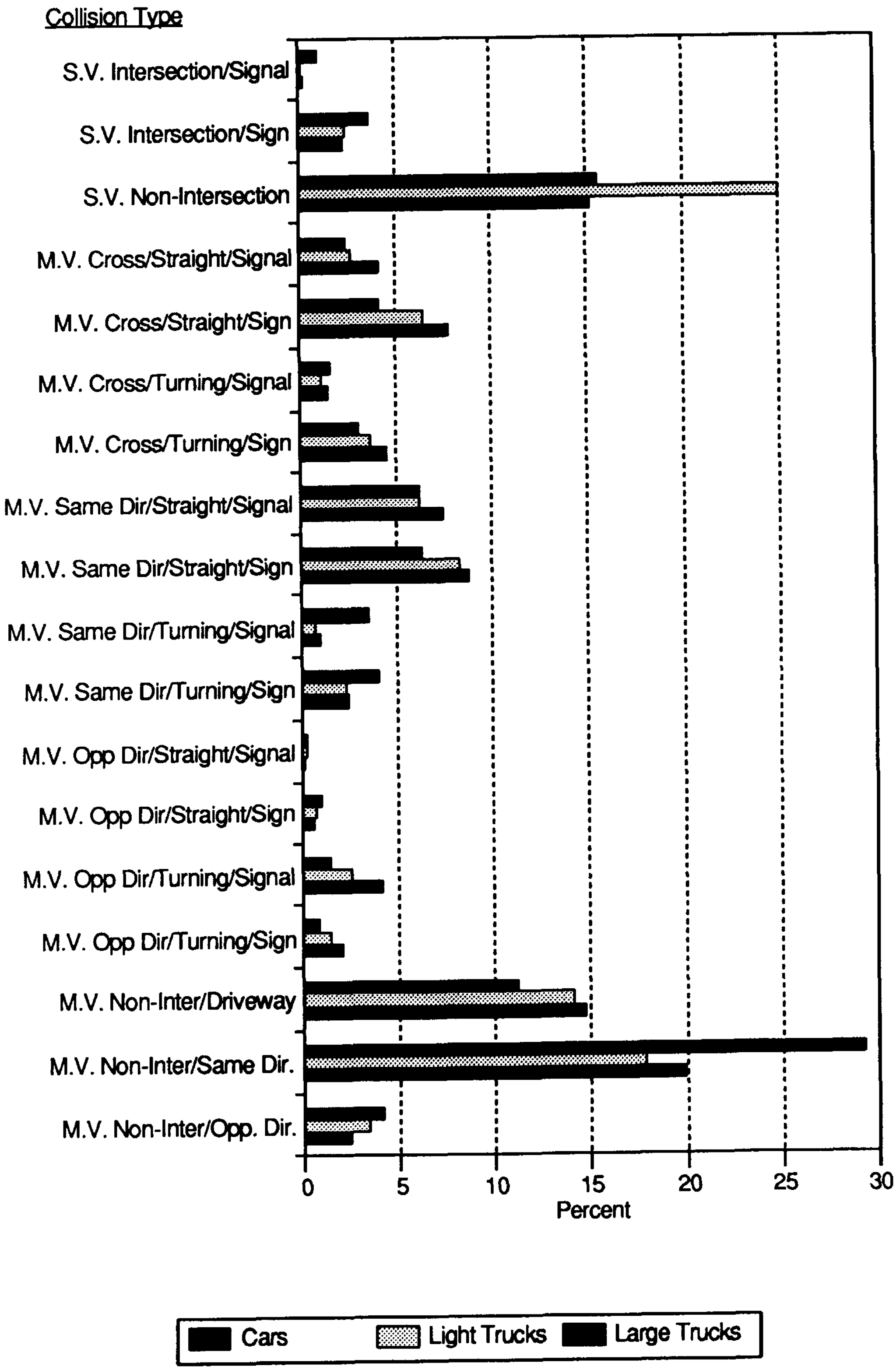

Fig. 3. Collision type by vehicle type, Michigan 1989.

driveway/parking accidents and higher incidence of nonintersection, same direction collisions. These comparisons across vehicle type illustrate the need for exposure data. While differences in collision experience between different types of vehicles should be considered in the application of collision avoidance technology, it is beyond the scope of this paper to explore the issue further. The remaining distributions in this section will be restricted to passenger cars.

Road surface condition. Figure 4 presents the collision typology for passenger cars in the Michigan 1989 file according to the road surface condition at the time of the accident. Over 24% of the involvements taking place on snowy/icy roads were single-vehicle, nonintersection collisions, compared to 14% of the involvements on dry roads and 10% on wet roads. Snowy/icy roads were also overrepresented in the nonintersection, opposite direction group. There was a high incidence of wet roads among nonintersection, same direction involvements and among same direction intersection involvements where both vehicles were going straight.

Accident severity. In addition to prevalence, accident severity should be considered when evaluating the potential of collision avoidance technology. The passenger car cases in the Michigan file are split in Fig. 5 into fatal, injury, and property-damage-only (PDO) involvements. Over 28% of the fatal involvements were multivehicle, nonintersection, opposite direction collisions, compared to just 3% of the injury involvements and 2% of the PDOs. Fatal involvements were also overrepresented in the crossing paths, both straight, at signed intersections group. On the other hand, fatal involvements were underrepresented among driveway/parking collisions, same direction, nonintersection collisions, and all four categories of same direction, intersection collisions. Another interesting difference is the lower percentage of single-vehicle, nonintersection collisions among injury-producing involvements (8.7%) compared to both fatals (17.1%) and PDOs (17.4%). In general, these findings are a reflection of a higher probability of fatality in rural accidents where travel speeds are generally higher than in urban areas.

Driver factors. Driver age is another important factor since the perceptions and reaction times of drivers vary with age, as do the exposure patterns. The Michigan cases were divided into three groups of drivers, those age 16 to 25; 26 to 55; and 56 and older. Underage drivers had previously been excluded from the analysis file. In Fig. 6 the collision distribution is compared among these three age groups and among alcohol-involved drivers of all ages. The alcohol-involved drivers are the primary group excluded from the previous analyses. The main differences in the collision distributions in terms of age are between the older drivers compared to the two younger age groups. Drivers 56 and older were found to have higher percentages of driveway/parking involvements and crossing paths, both vehicles moving straight collisions, both at signed and signalized intersections. The older drivers had lower percentages of single-vehicle, nonintersection involvements compared to the other two age groups.

Comparing the impaired and unimpaired drivers, Fig. 6 indicates a preponderance of single-vehicle accidents among the alcohol-involved drivers. Nearly 41% of the involvements of alcohol-involved drivers were single-vehicle accidents at nonintersections, compared to about 15% for the three unimpaired groups. The great overinvolvement of alcohol-involved drivers in single-vehicle accidents makes it difficult to evaluate their distribution of multivehicle collisions compared to unimpaired drivers by examining Fig. 6. If the three categories of single-vehicle accidents are excluded from consideration, other differences emerge between impaired and unimpaired drivers. Considering multivehicle accidents only, the alcohol-involved drivers experienced more nonintersection, opposite direction collisions; same direction, both straight, at signalized intersection involvements; and opposite direction, both straight, at signed intersection collisions compared to the unimpaired drivers.

Environmental factors. Table 2 compares the collision distribution according to three environmental variables: land use (rural/urban), road class, and light condition, again using the 1989 Michigan file of passenger cars. Rural areas were defined as a community under 5,000 in population or a township of any size. Road class was split into all limited access routes and major arteries versus all other types of roads. Light condition was compared between daylight versus dark, dawn, and dusk combined. The table compares these three factors individually and as an eight-level variable that reflects all combinations of the three variables.

The biggest difference in terms of land use is that 30% of the rural involvements were single-vehicle, nonintersection collisions, compared to just 5% of the urban involvements. Because of this difference, most of the percentages for the multivehicle categories were higher among urban than rural accidents, although the proportion of multivehicle, nonintersection, opposite direction collisions among the rural involvements was over twice as high as among the urban involvements. Considering road type, multivehicle, same direction, nonintersection accidents were over twice as common among involvements taking place on limited access/major arteries com-

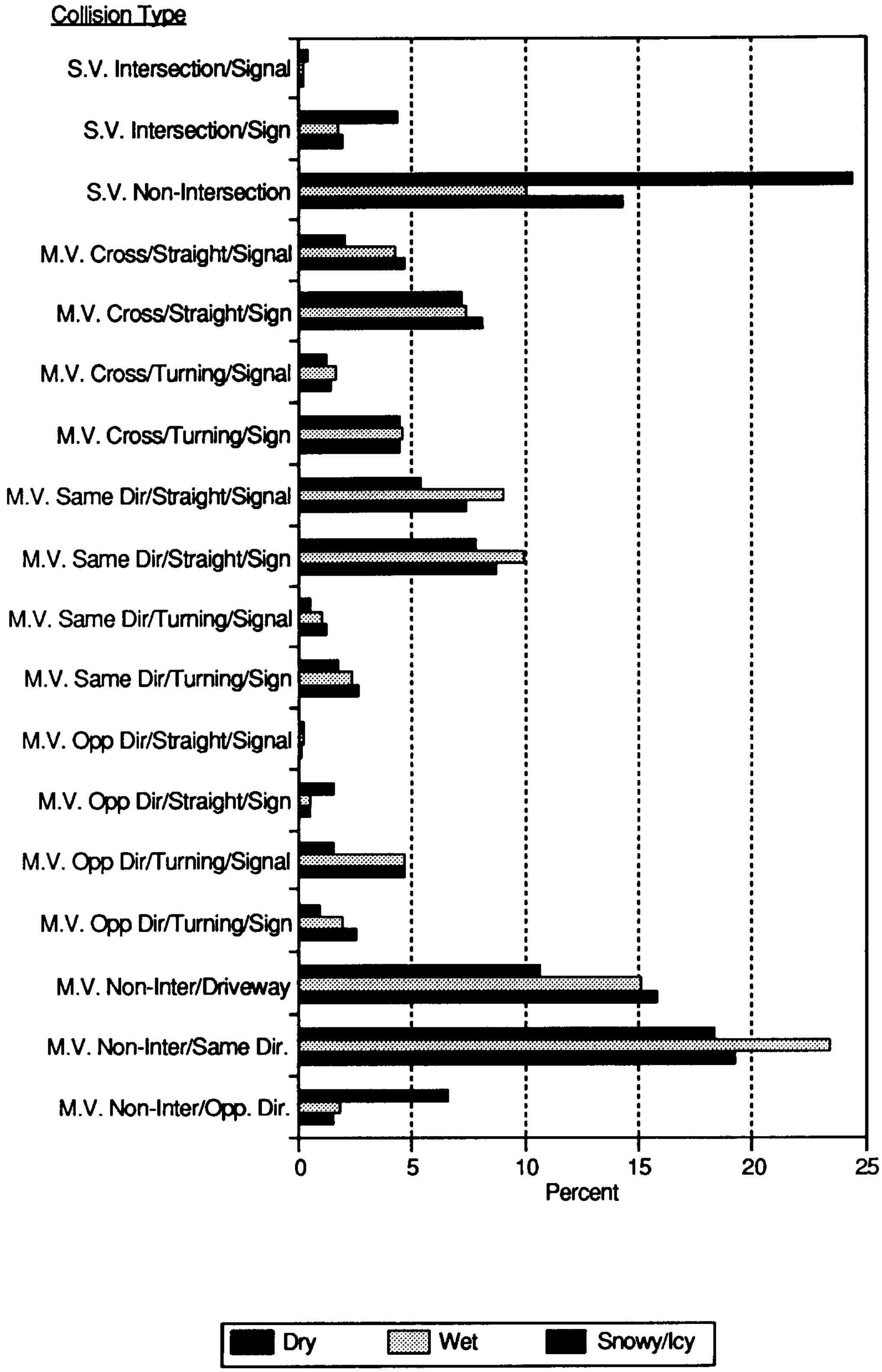

Fig. 4. Collision type by road surface condition, passenger cars only, Michigan 1989.

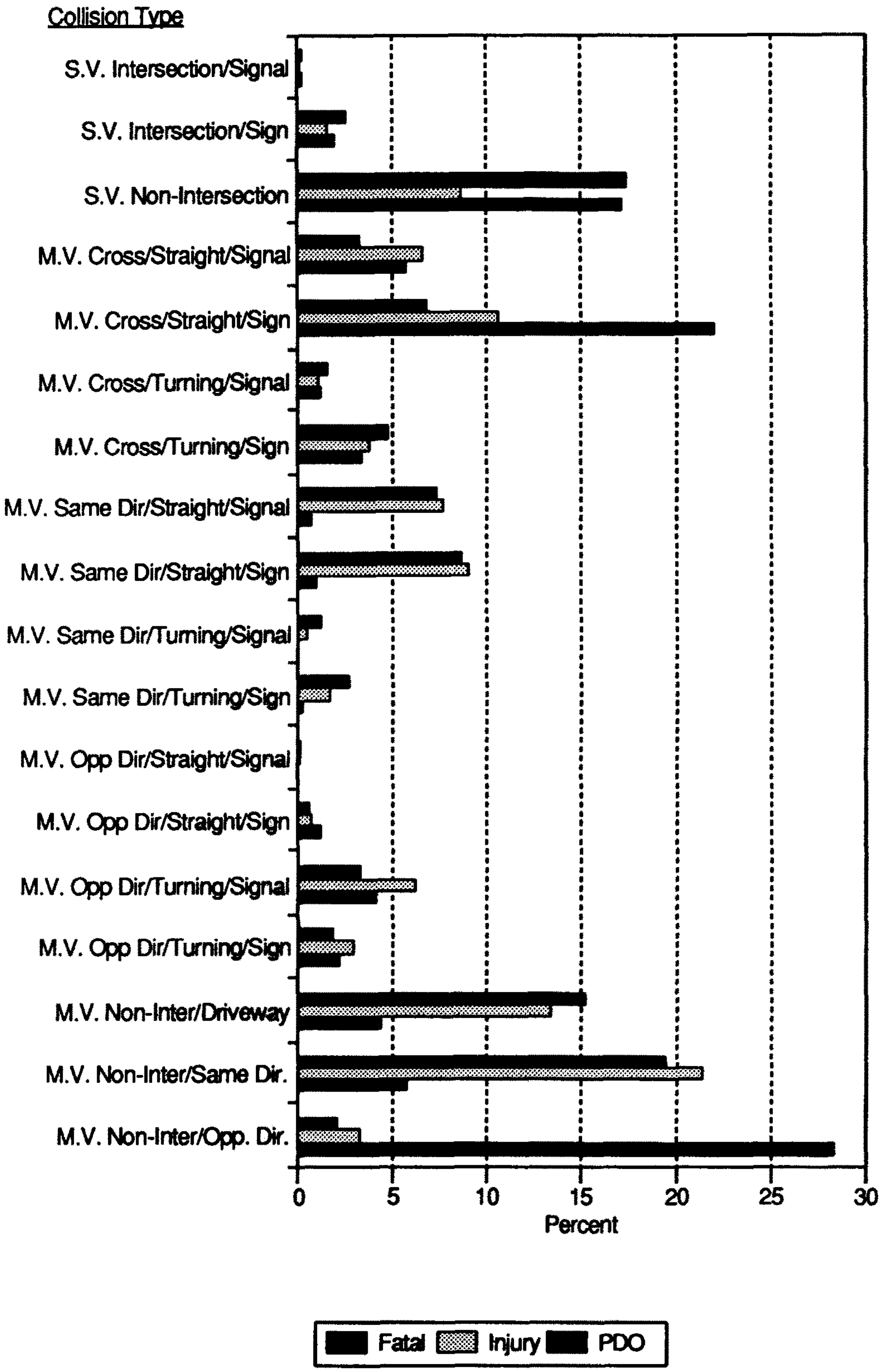

Fig. 5. Collision type by accident severity, passenger cars only, Michigan 1989.

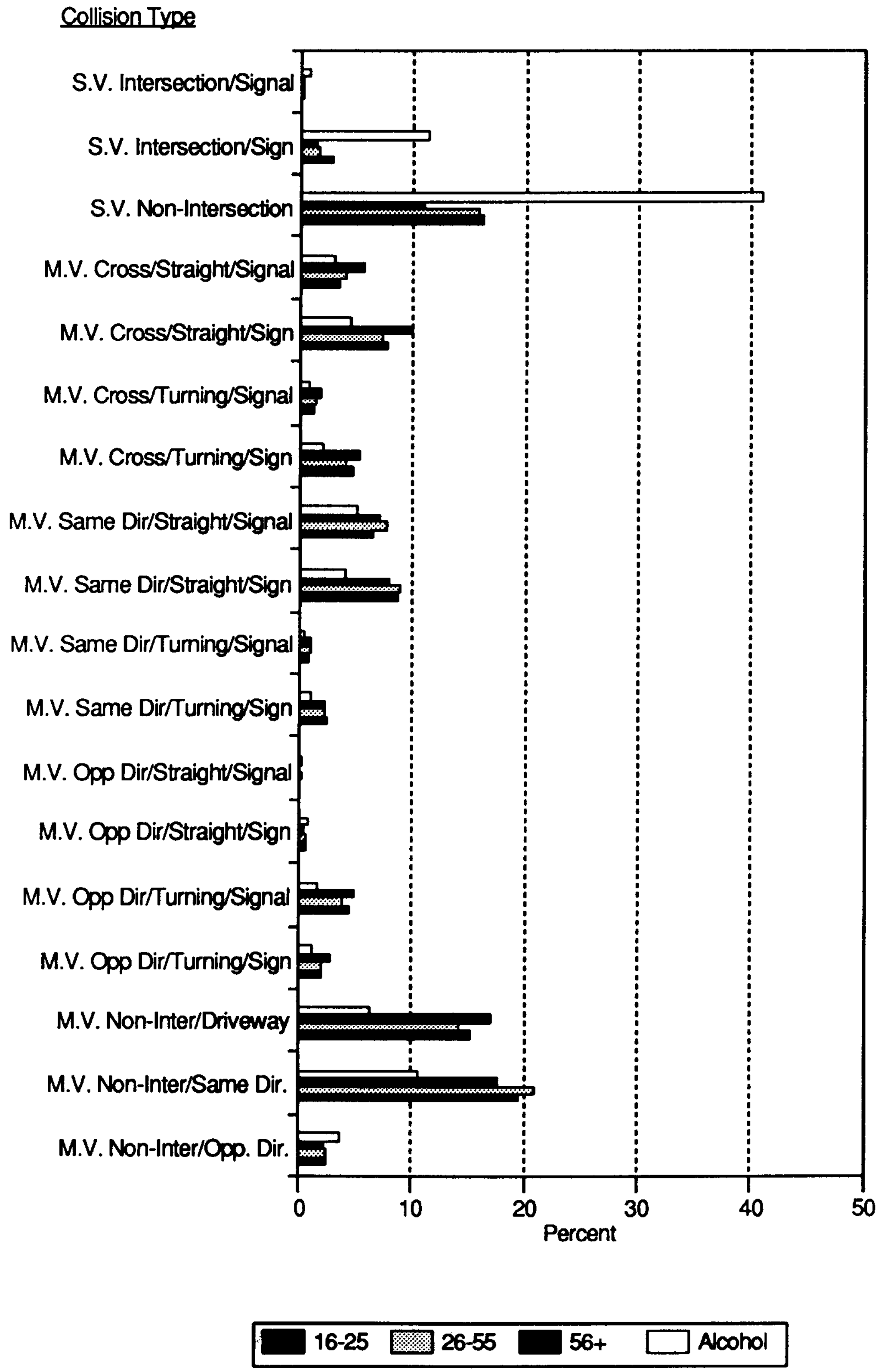

Fig. 6. Collision type by driver age and for alcohol-involved drivers, passenger cars only, Michigan 1989.

Table 2. Collision type by land use/road class/light condition, passenger cars only, Michigan 1989

Land use/road class/light condition	SV Int Signal	SV Int Sign	SV Non-int	MV Cross Str Signal	MV Cross Str Sign	MV Cross Turn Signal	MV Cross Turn Sign	MV Same Str Signal	MV Same Str Sign	MV Same Turn Signal	MV Same Turn Sign	MV Opp Str Signal	MV Opp Str Sign	MV Opp Turn Signal	MV Opp Turn Sign	MV Non-int D/W	MV Non-int Same	MV Non-int Opp	Total
Urban/Maj/Day	0.3	0.8	3.8	6.6	3.2	2.1	3.2	12.4	10.9	2.2	2.1	0.2	0.3	4.2	1.9	10.7	34.0	1.2	100.0
Urban/Maj/Dark	0.5	1.9	9.3	6.4	3.3	2.0	2.3	11.0	9.1	1.5	1.9	0.2	0.5	4.1	1.2	7.8	35.5	1.5	100.0
Urban/Oth/Day	0.2	2.0	3.1	5.4	12.9	1.7	5.7	8.8	10.2	1.4	2.9	0.2	0.8	5.8	3.0	18.2	15.8	1.7	100.0
Urban/Oth/Dark	0.6	5.7	10.6	5.9	10.5	2.0	4.5	8.7	8.9	1.3	3.2	0.4	1.3	6.1	2.4	12.6	12.7	2.7	100.0
Rural/Maj/Day	0.1	1.4	13.9	2.3	5.2	1.2	4.2	5.5	9.9	0.5	2.9	0.1	0.5	2.9	2.0	17.0	27.1	3.2	100.0
Rural/Maj/Dark	0.2	2.4	50.2	1.9	2.8	0.8	2.1	3.0	4.6	0.3	1.4	0.1	0.5	2.1	0.9	8.0	16.3	2.7	100.0
Rural/Oth/Day	0.1	2.4	18.4	1.6	9.7	0.9	6.9	3.4	7.5	0.3	2.6	0.1	0.9	2.9	2.5	21.6	14.0	4.4	100.0
Rural/Oth/Dark	0.2	4.6	58.4	0.9	3.5	0.5	2.5	2.0	3.5	0.2	1.3	0.1	0.7	1.7	1.0	7.7	7.6	3.7	100.0
Urban	0.3	2.2	5.0	5.9	9.0	1.9	4.5	10.0	10.1	1.6	2.6	0.2	0.7	5.3	2.4	14.3	22.2	1.7	100.0
Rural	0.1	2.6	30.0	1.7	6.1	0.9	4.5	3.6	6.9	0.3	2.2	0.1	0.7	2.5	1.8	15.4	16.7	3.6	100.0
Major	0.2	1.4	14.6	4.6	3.7	1.6	3.2	8.8	9.4	1.3	2.2	0.1	0.4	3.5	1.7	11.7	29.5	2.1	100.0
Other	0.3	3.0	15.6	3.9	10.5	1.4	5.4	6.5	8.4	0.9	2.6	0.2	0.9	4.6	2.5	16.8	13.8	2.8	100.0
Daylight	0.2	1.7	8.2	4.4	8.8	1.6	5.1	8.0	9.7	1.2	2.6	0.2	0.7	4.4	2.5	17.0	21.4	2.4	100.0
Dark	0.4	3.9	32.6	3.7	5.5	1.3	3.0	6.0	6.5	0.8	2.0	0.2	0.8	3.6	1.5	9.3	16.3	2.8	100.0
Total	0.3	2.4	15.2	4.2	7.8	1.5	4.5	7.4	8.8	1.1	2.5	0.2	0.7	4.1	2.2	14.8	20.0	2.5	100.0

pared to other roads. Involvements on other roads were characterized by higher proportions of crossing paths at signed intersection accidents and driveway/parking collisions compared to the limited access routes and major arteries. Comparing the collision typology according to light condition, the main difference is that 33% of the involvements during darkness were single-vehicle, nonintersection collisions, compared to only 8% of the involvements that took place during daylight. Driveway/parking accidents and multivehicle, nonintersection, same direction collisions were more common during the day than at night.

When the three environmental variables are considered simultaneously, it is apparent that specific sets of conditions are associated with particular types of collisions. For example, 50% of the rural involvements on major arteries during darkness and 58% of the rural involvements on other roads during darkness were single-vehicle, nonintersection collisions. The highest proportions of crossing paths, both straight, at signed intersection involvements were found on urban, other roads, during the day (12.9%) and urban, other roads, while dark (10.5%). Multivehicle, same direction, nonintersection collisions had the highest representation in urban areas on major arteries during the day (34.0%) and at night (35.5%). These tabulations underscore the differences in the accident experience in different operating environments and illustrate the need for exposure data so that relative risk may be determined.

THE REVIEW OF POLICE ACCIDENT REPORTS

State computerized collision files do not contain all of the information represented on police reports, especially that described in the narrative and diagram. Therefore, as a final step in the project, five collision type subsets were selected for case studies, and a sample of Michigan police reports from 1988 was drawn to examine these collision scenarios in greater detail. By examining this additional information, the investigators hoped to assess whether the computer file-based collision type categories accurately summarized the salient features of the precollision scenario and to discover additional factors that might be associated with certain types of collisions. The collision types selected were driveway/parking collisions; single-vehicle, nonintersection collisions; same direction, nonintersection collisions; and two crossing paths collision types, those at signalized intersections and those at nonsignalized intersections. In addition to the intrinsic interest of each of these collision types, the five selected subsets account for about two-thirds of all involvements in the typology for each of the four datafiles analyzed (Michigan, Washington, NASS, and CARDfile).

A total of 209 cases in the five categories was obtained from the Michigan State Police records, sampling randomly within a total of 32 strata. The strata, which were defined by driver age, land use, light condition, and the collision type scenarios, were used in order to ensure that there would be adequate representation of various factors of interest in the case study sample. A total of 40 cases of single-vehicle, nonintersection collisions was reviewed; 18 of crossing paths at signalized intersections; 55 of crossing paths at nonsignalized intersections; 59 in the driveway/parking category; and 37 cases of nonintersection, vehicles moving in the same direction.

Single vehicle, nonintersection

Fifteen of the 40 cases examined involved hitting an animal—12 times it was a deer. An additional computer run on the Michigan file showed that animals are involved in 10% of all police-reported accidents in Michigan, and that 44% of nonpedestrian, nonintersection, single-vehicle accidents involved striking an animal. Three-quarters of these collisions were in rural areas after dark. Other major categories involved striking a fixed object (32.5%), overturning (7.7%), and striking a parked vehicle (12.1%). Snowy/icy roadways and younger drivers were overrepresented in each of these latter three categories.

Crossing paths at a signalized intersection

In the 18 cases where the vehicles were crossing paths at intersections with functioning three-color traffic signals, the most common problem was one vehicle simply proceeding into the intersection when the signal was red. Only two of these involved a legal right turn on red. In 12 of the remaining 16 cases, the at-fault driver was clear, while in four cases, both of the colliding drivers claimed to have a green light. Older drivers were slightly overrepresented among the at-fault drivers.

Crossing paths at a nonsignalized intersection

Fifty of the 55 cases of vehicles crossing paths at a nonsignalized intersection involved one vehicle failing to yield at a stop sign, yield sign, or flashing red light. Two of the collisions involved a right-turning vehicle striking a vehicle waiting at a stop sign, and three of the collisions were at uncontrolled intersections (one because the traffic signals were inoperative). The failure-to-yield collisions provided one of the more interesting findings of the hardcopy review.

The cases tended to fall into two major categories. Older drivers were frequently described as stopping at the stop sign before pulling out and colliding with an oncoming vehicle. Among involvements of younger drivers, typically no claim of having stopped was reported in the police narrative.

Driveway/parking

The investigators expected the scenario of a vehicle backing from a driveway or parking spot into traffic to be common among the driveway/parking involvements. In fact, only 6 of the 59 cases involved a vehicle backing. Only one of the 59 cases happened to take place at a parking spot. Of the 23 cases leaving a driveway, 12 involved turning left, 7 involved turning right, and 4 involved backing out. Of the 35 cases entering a driveway, 25 involved turning left, 9 involved turning right, and one involved backing in. Clearly, left turns are a particular problem in these collisions. Many of the accidents took place in driveways located adjacent to intersections, which may have contributed to the confusion leading to the collision. Almost 17% of the cases involved the rear ending a car stopped or slowing to turn into a driveway. Another 15% involved an attempt to pass a vehicle turning into a driveway.

Same direction, nonintersection

Finally, of the 37 cases of vehicles colliding while traveling in the same direction away from intersections, 24 involved striking the rear of a vehicle in the same lane—usually one that was slowing down, or stopped, for a traffic light or to make a turn or due to general congestion. The remaining 13 cases involved sideswipe collisions of vehicles passing, changing lanes, etc. Eight of the 24 rear-end collisions involved chains of three or four vehicles. Wet or snowy pavements were far more common among the freeway rear ends than among those occurring on other roads. For the same direction, nonintersection cases in general, both younger and older drivers were overrepresented among the at-fault drivers in the sample.

DISCUSSION

The design of collision avoidance technology and estimates of the potential effectiveness can only be enhanced by a more accurate and detailed description of the actual collision experience. Expected benefits may not be realized if technology is implemented on the basis of an insufficient analysis. The review of selected police accident reports is an essential element of the analytical process. The research team selected variables for the collision typology because they were expected to characterize those elements of the precollision situation that were pertinent to the identification of possible collision avoidance countermeasures. Accidents within a particular collision type are expected to be more similar in terms of potential collision avoidance countermeasures than accidents in a different category of the typology.

The case review was the only means available to evaluate the utility of the resulting typology. In general, the five categories examined, making up about two-thirds of all involvements, appeared homogeneous within categories and heterogeneous across categories. For example, the single-vehicle, nonintersection group occurred primarily in rural areas after dark. The most common object struck was an animal. However, differences within this accident category were apparent. While slippery roads were not overinvolved in the collisions with animals, nearly one-fourth of the remaining collisions in this group did occur on slippery surfaces. "Obstacle detection technology" has been proposed for single-vehicle collisions in general. While this may be appropriate for the deer impacts, obstacle detection will not be effective in the remaining collisions where the vehicle has lost control due to a slippery surface before leaving the road and then striking an object.

Another interesting finding from the case review was that older drivers tend to act differently at signed intersections than younger drivers. The older drivers often stop and then pull out inappropriately, while the younger drivers more often fail to stop altogether. Further study is necessary to verify this pattern. If it is consistent, it has important implications for the types of collision avoidance devices that would be effective.

In summary, the authors feel that this analysis has demonstrated that an accurate and detailed description of the accident experience can make an important contribution to the design and estimation of the potential benefits of collision avoidance technology. This work is an essential element of the IVHS program to develop Advanced Vehicle Control Systems. While there is much more that can be learned from existing data, we also see a clear need for additional data focusing on the precollision situation. Future work is described in the last section.

FUTURE WORK

The process of creating the most useful typology of collision situations to assist in the development of vehicle or highway collision avoidance technologies is far from complete. One area for future work lies in the area of data collection. Current coding of collision data emphasizes crashworthiness, not collision avoidance. Collision type, for example, is coded on accident reports for the first harmful event, which is not necessarily indicative of the precrash paths of the vehicles. Viable coding systems must be developed for accurately recording detailed precollision information as part of the original accident report. This information is essential if the developing advanced technologies are to address real, as opposed to perceived, problems.

As discussed earlier, another data collection need concerns exposure estimates. Accurate information on vehicle mileage crosscut by such factors as traffic density, road class, land use, and light condition is needed to gauge the risk of involvement in particular types of collision. Performing risk assessments would help in establishing priorities for competing countermeasures.

More easily accomplished, short-term goals involve utilizing already extant data. The hardcopy case studies of particular collision types showed that similar vehicle movements and relationships were involved in different collision types. For example, striking the rear of vehicles slowing in traffic occurred in both driveway-related and same direction, nonintersection collisions. Many of the accidents included in the driveway/parking group could be redistributed to the intersection categories in future iterations of the collision typology. From the point of view of technological interventions, a typology based on precollision vehicle movements and spatial relationships promises to be more directly applicable to collision avoidance research.

Cases involving opposite direction collisions both at and away from intersections are less frequent but generally more serious collision situations. Crash avoidance devices or techniques that prevent these would potentially have a larger payoff than those that concern less serious accidents. In general, collision severity should be included along with frequency in ranking collision scenarios.

Analyses of a two-vehicle datafile would yield more detail about collision types. In such a file, the data from both vehicles in an accident, such as the ages of the two drivers or the movements of the two vehicles, would be brought together in one record per collision. This would permit analysis of the interaction of drivers of different age groups in various collision situations and of the specific intended precrash movements of each vehicle involved in an accident.

New versions of the collision typology should be tested on additional datafiles. The same applies to hardcopy review of police reports. Most of the data used for this paper came from Michigan's collision files. Additional analyses need to be conducted on collision data from other states or countries that differ from Michigan in terms of climate, topography, population density, and other factors.

In closing, it must be emphasized that this is research that should be addressed immediately, before further countermeasure development occurs and before choices among countermeasures are made. The process of creating collision typologies needs discussion and refinement, and new priorities for data collection need to be developed. This work addresses the definition of the problem. Without adequate problem definition, the risk is greater that countermeasures may be developed, and even implemented, for problems that do not exist, while opportunities for real improvements are missed.

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