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ANALYSIS OF OPERATIONS AND SAFETY OF Y-INTERSECTIONS

VOLUME III: EXECUTIVE SUMMARY

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16. Abstract

Accident experience at unsignalized, two-way intersections, where the major road curves to the right and the side road continues on a tangent to the curve, was examined with the goal of determining whether this type of intersection has accident problems more severe than other types of three-legged intersections.

The study included a review of case studies of severe accidents at these sites, analysis of data from a Y-intersection improvement program from Washtenaw County, Michigan, and analysis of accident data from three-legged intersections on the Michigan state trunkline. Field observations were made at 53 sites. A survey was conducted of state Departments of Transportation concerning their experiences with this type of intersection.

The analyses show that this special type of Y-intersection does not pose a unique risk relative to other three-legged intersections. Its accident patterns are similar to that of all curved Y-intersections. The criteria used for selecting curved Y-sites for safety improvements are sufficient for identifying problem sites among the special Y-intersections also.

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Many members of the University of Michigan Transportation Research Institute staff contributed to this project. Dr. Paul E. Green developed the method of Bayesian estimation of rates, used in the statistical modelling of this research, as part of his Ph.D. dissertation. He also performed the statistical tests required in the analyses. Cecil Lockard and Raymond Masters performed the field studies, and Professor Leland Quackenbush carried out the interviews of the State Departments of Transportation. Dr. Kenneth Campbell served as project director and offered his insights throughout the project. We gratefully acknowledge their contributions.

EXECUTIVE SUMMARY

Introduction

This research examined accident experience at a special configuration of the Y-intersection, where the major road curves to the right and the side road continues on a tangent to the curve as shown in Figure 1. This type of intersection is called a special right Y-intersection in this study.

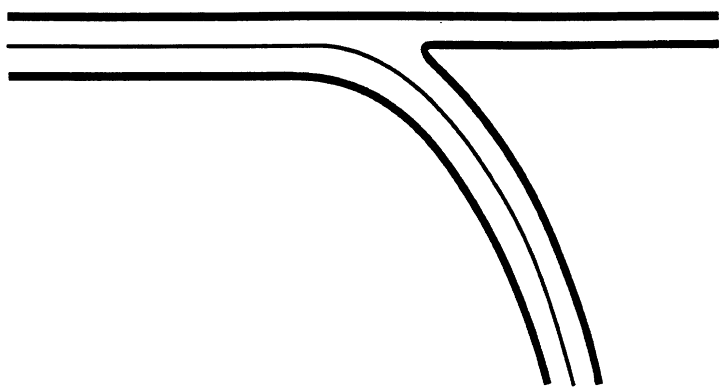

Figure 1 - Y-Intersection with Main Road Curving Right and Crossroad on a Tangent

The special right Y-intersection and its mirror image, the special left Y-intersection, were not designed deliberately but are a consequence of the pattern of the original section roads of Michigan that followed the land surveys. Over time, the main roads were built to favor the major traffic flows. These Y-intersections often resulted when abrupt changes in alignments were required for the main road to follow the section roads. Many of these Y-intersections still exist today. Most sites are in rural areas but there are some in urban areas. While most are on local roads, some can be found on the Michigan state trunkline road system.

There are obvious problems with special right Y-intersections. A vehicle turning left from the main highway to the crossroad at the locations where the main road curves to the right has to travel a considerable distance in the opposing traffic lane, thus increasing the opportunity for a collision with an oncoming vehicle. A driver intending to go straight ahead to the crossroad might not perceive that he/she must yield to traffic. A driver unfamiliar with the intersection could be drawn to the crossroad, especially under low-light conditions, and cross the opposing lane unintentionally. A vehicle on the crossroad attempting to turn left onto the main road must perform a difficult maneuver and may have a sight-distance problem in observing traffic approaching from the left.

Whether the scenarios described above translate into an abnormally high accident frequency has never been systematically studied. Before remedial action can be taken, it is necessary to determine if an accident problem does exist and to understand the nature of the problem in terms of accident types and circumstances.

This research addressed this problem mainly through the comparison of the accident experience at special right Y-intersections with that of other types of Y-intersections and that of Y-intersections with T-intersections using geometric and accident data from the Michigan trunkline system. Before the analysis of the trunkline data was undertaken, case studies of severe accidents at special right Y-intersections were examined to formulate questions and develop hypotheses. The literature was reviewed from the perspective of accident studies and human factors, and a survey of 25 state departments of transportation concerning their practices and policies toward these special configurations of Y-intersections was conducted. An information file collected by the Washtenaw County Road Commission for their Y-intersection improvement program was reviewed and analyzed. The research also included field observations at 53 special Y-sites throughout the state.

Case Studies

A review of eight case studies from the MDOT litigation files of serious crashes at special right Y-intersections showed that in 6 of the 8 cases the driver failed to yield the right-of-way to oncoming traffic and attempted to proceed straight. Figure 2 shows the prevailing pattern of these accidents. The ambient conditions were consistently good and the pavement was dry. Sight distance was good and, with one exception, the accidents occurred in daylight. The drivers who did not yield the right-of-way were known to be familiar with the intersection in most of these cases and, except for one case, alcohol or other controlled substances were not present.

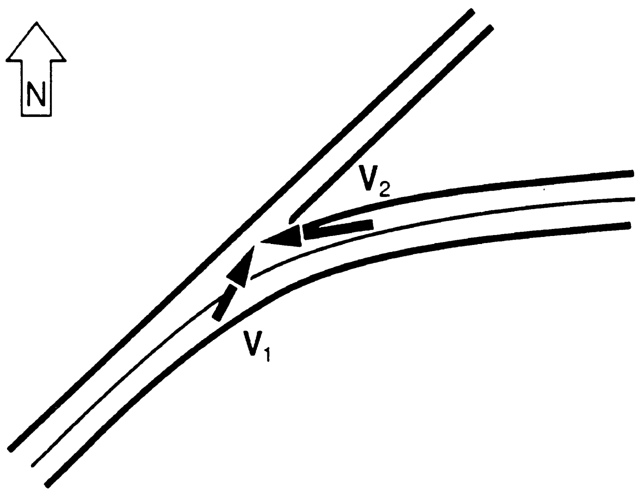

Figure 2 - Scene Diagram of Typical Litigation Case

Accident frequencies were available for three of the cases and were not high enough to merit notice. However, closer examination showed a pattern of head-on accidents at these three sites. In addition, one of the case studies provides evidence of speeding on curves.

The review of the case studies led to the following set of questions:

1. Do drivers approaching the intersection with the intent of going onto the minor road believe that they have the right-of-way? Is there something inherent about these special Y-intersections that leads drivers to assume that they have the right-of-way?

2. Do the special right Y-intersections have more head-on accidents than other three-legged intersections?

3. Can single-vehicle accidents at the special Y-intersections be attributed to the curve rather than the intersection itself?

4. Do drivers, unaccustomed to encountering oncoming traffic at the special right Y-sites in low-volume environments, simply forget to look for oncoming traffic?

5. Are drivers genuinely confused by the geometry of the special right Y-intersection?

6. Are the accidents reviewed in these cases typical of accidents at special right Y-intersections, or are these rare occurrences?

Literature Review

Y-intersections have been criticized since the earliest days of the traffic engineering profession. The major shortcomings are that the Y-configuration introduces movements that are head-on in nature and forces motorists to turn their heads at awkward angles to check for traffic on the other legs of the Y. It creates larger open areas than would occur at an intersection closer to a right angle, which increases the number of possible routes and encourages violations.

Early AASHO policy found the Y-intersections acceptable under certain circumstances. However, since 1984, the AASHTO policy on geometric design has been that no new three-legged intersections with acute angles be built. AASHTO policy does not specify that all existing Y-intersections be immediately rebuilt. Many state departments of transportation are systematically removing Y-intersections from their trunklines.

Studies that have examined the safety of the Y-intersection find that Y-intersections have higher accident rates than comparable T-intersections. Efforts to relate accident experience at Y-intersections to geometric features and traffic volumes and to develop a set of causal accident models have not been successful.

A comparison of the possible types of errors made by the drivers in the case studies with the human causal factors of traffic accidents found in the literature points to the errors being either recognition or decision errors. These may involve improper assumptions about right-of-way, failure to look, or improper driving actions, which may be habitual, but the risk of which is not apparent to the driver.

The particular geometry of the special Y-intersection has been used by human factor psychologists as a classic example of a perceptual trap, i.e., a visual optical illusion. Work on driver expectation also indicates that the characteristics of the special right Y-intersection are not consistent with driver expectation.

The argument that develops from the literature on driving behavior is that the configuration of the special right Y-intersection may contribute to the errors which, under certain circumstances, result in accidents.

Review of Other States

A telephone survey of 25 state departments of transportation was conducted to obtain information about their policies toward Y-intersections in general, their experiences with the special right Y-intersection, and the type of treatments that they either use or would suggest for the special right Y-intersection.

Of the 25 states, 18 responded that they have only a few of the special Y-sites and that these are located in rural areas and carry low volumes of traffic. The other seven stated that they have from some to many such sites also located in rural and low-volume environments.

The policies in all states contacted are that Y-intersections are not used in new construction and are to be eliminated on existing roads if there is a safety problem or as the road is improved. One quarter of the states stated that they had a formal program to eliminate Y-intersections. Another quarter responded that the Y's were being eliminated as a normal consequence of upgrading and improving roads, and half stated that the Y-intersections were being eliminated on a case-by-case basis and reconstructed if there was a safety problem.

All 25 respondents recommended reconstruction to a T-intersection as the best possible treatment for such an intersection. Several suggested minor modifications to "jug-handle" the side road or otherwise turn it to meet the main road at an angle at most 20 degrees from the perpendicular.

If the intersection is not modified to a T, other options suggested by the respondents included signing improvements, addition of room for passing, flashers, and, in some circumstances, channelization. The consensus was that signing should be reviewed first. If necessary, advance-warning signs of the curve ahead and of the side road should be posted. It was suggested that if the side road is controlled by a yield sign, the yield sign should be replaced with a stop. Stop-ahead signs on the side road were also advised, as was the marking of sharp curves with chevrons.

Thirteen of the respondents stated that additional room for turning vehicles could be provided at the intersection either by a left-turn pocket or "passing blister," also called a "fly-by lane," on the right. All indicated that this treatment depends on the traffic volume and either the available road width or right-of-way.

A synthesis of the responses indicates that the flasher should only be considered at a special right Y-intersection after a thorough review of the site. Consideration must be given to visibility, line-of-sight, and traffic volumes. The consensus of opinion was that channelization should be considered on a case-by-case basis. However, most would not use channelization in low-volume or rural areas.

Analysis of Washtenaw Y Data

Accident records for forty-five low-volume Y-intersections in Washtenaw County were examined over two five-year periods, before and after 1985, when changes were made to signing at the intersections and approaches.

From the various analyses of the Washtenaw Y-intersections, it appears that the special right Y-intersection has an accident experience quite similar to that of other types of Y-intersections. The prevalent accident type at these sites is the run-off-road accident at about 70% of all accidents. Head-on accidents accounted for 4%, and rear-end accidents accounted for 3% at the special right Y-intersections.

The analysis of the accident data before and after the sign upgrades found no change in the accident experience between the two time periods. It should be noted that all the sites were signed in the before period and the upgrades consisted of incremental improvements.

Analysis of MDOT Trunkline Data

Sample

The population of 9,667 two-way, non-signalized, three-legged intersections on the state trunkline, as found by matching records between the Michigan Department of Transportation MIDAS III and Sufficiency Files, was used to develop the database for analysis. The intersections were classified as curved or tangent, rural or urban, and T or Y. The study design called for approximately equal cells of the various categories. Therefore, if the cell size for a particular category was over 250 sites, the cell was sampled. If a cell size was less than 250, all sites were retained. All curved Y-sites were retained because they would be further subdivided. The final study sample consisted of 2,067 two-way, non-signalized, three-legged intersections. Figure 3 shows the final study sample.

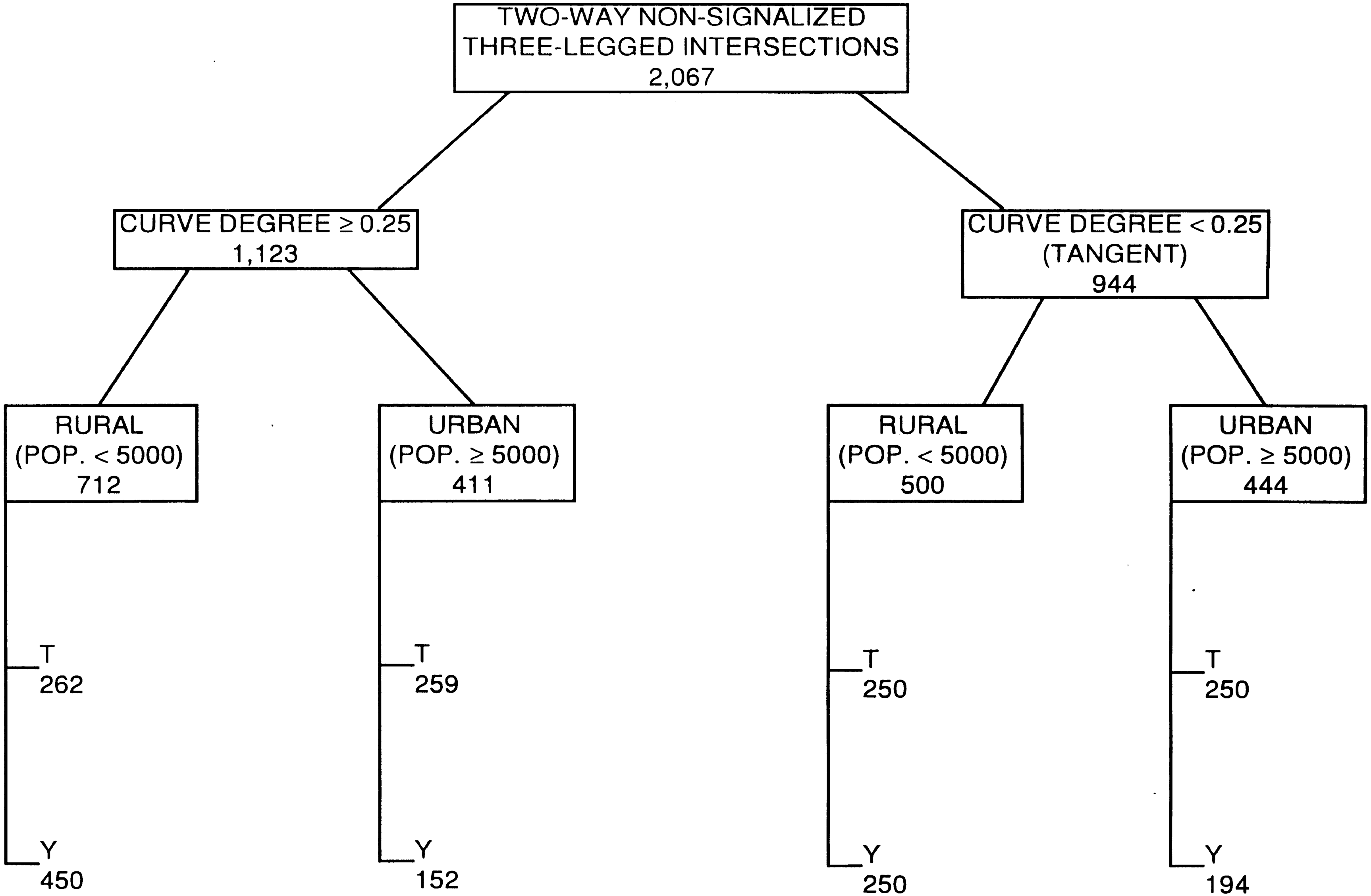

Figure 3 - Final Study Design

Comparison of Y versus T accident rates

Accident rates per 100 million vehicles were calculated for eight categories of intersection type by taking the total number of accidents for all the members of a category for a period of time and dividing by their total volume over the same period of time. The method itself has a long tradition in the field of epidemiology for the determination of relative risk of various categories of subjects and has been used extensively in traffic safety research whenever comparisons across categories are important.

In this way, accident rates could be compared between Y and T sites that were similar in terms of trunkline horizontal alignment and area type. Estimates of standard errors necessary for statistical comparisons of rates were obtained by fitting models of accident and volume data using Bayesian estimation techniques. These techniques yield robust estimates, even when the data are sparse, which is the case for relatively small numbers of accidents observed over long exposures. The major findings of this analysis are summarized below.

- Y's had higher accident rates than T's for curve/rural, tangent/rural, and tangent/urban intersections. T's had higher rates among curve/urban intersections.

- This overall pattern tended to hold when rates were compared controlling (separately) for MDOT district, degree of curvature, rural/urban development, and speed limit.

- In general, higher accident rates were observed in the more populous MDOT districts, at sites with higher degrees of curvature, and in more urbanized areas.

- Accidents at curve sites tended to be more severe at Y-intersections than T-intersections. At tangent sites, the severity distributions for Y's and T's were about the same.

- At rural intersections, Y's had more accidents per site than T's, both overall and in each severity category. At curve/urban intersections T's had more low-severity accidents per site than Y's. At tangent/urban sites, Y's and T's had comparable numbers of accidents per site, both overall and at each severity level.

- At rural intersections, Y's consistently had higher accident rates than T's at all three levels of accident severity. Rates were more variable according to severity for urban sites. Among curve/urban sites, Y's and T's had comparable rates of the most severe accidents, while T's had higher rates of less severe and property damage accidents. Among tangent/urban sites, Y's and T's had similar rates for fatal and injury accidents, while Y's had higher rates of property damage accidents.

- Y's had higher rates than T's of both run-off-road and head-on type accidents for all categories of intersection type except curve/urban sites. This held for all levels of severity of run-off-road and head-on accidents, although some of the head-on rate differences were not significant. Y's also had a higher rate of these two accident types at curve/urban intersections for fatal and A-injury accidents, but not for less severe accidents.

- When rates were calculated controlling for volume, the overall patterns of Y's having higher rates than T's among rural sites was found to hold. This remained true for all levels of severity.

- Among curve/urban sites, T-intersections had a consistently higher rate than Y's in every volume category, although the difference was only significant in the highest volume category.

- Among tangent/urban sites, Y-intersections had a higher rate than T's in both the lowest and highest volume categories. T's had higher rates in the mid-volume categories. Mixed results were observed at different levels of severity.

<u>Comparison of special right Y versus other three-legged intersections</u>

The Y-sites were further classified by curve direction and location of the minor leg, whether the angle made with the main road was acute or obtuse, and whether the minor leg was on the inside or outside of the curve, as shown in Table 1. Figure 4 shows the definitions of the angles.

Table 1 - Definitions of Y-Intersection Categories

Y Category	Curve Direction	Location of Minor leg	Angle	Minor Leg on Inside or Outside of Curve
1	right	left	Obtuse	Outside
1	left	right	Acute	Outside
2	right	left	Acute	Outside
2	left	right	Obtuse	Outside
3	right	right	Acute	Inside
3	left	left	Obtuse	Inside
4	right	right	Obtuse	Inside
4	left	left	Acute	Inside
5	none	left	Obtuse	n/a
5	none	right	Acute	n/a
6	none	left	Acute	n/a
6	none	right	Obtuse	n/a

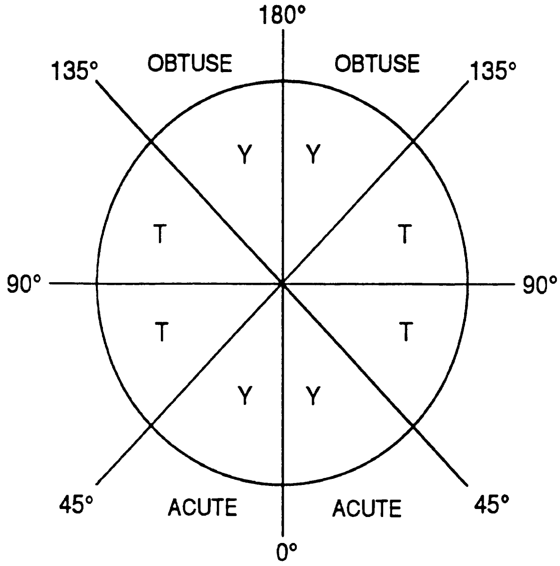

Figure 4 - Angles for Y and T Intersections

The special right Y-intersection formed a subset of one of the categories. Its mirror image, the special left intersection, also formed a subset of another category. Figure 5 shows the shapes of the categories of Y-intersections and Figure 6 shows the study sample categories by these definitions. In all there were 88 sites in the special right Y-category. These were not sampled but represent the entire population of special right Y-intersections on the state trunkline. Rates were calculated for rural versus urban areas, different accident severities, different accident types, and controlling for traffic volume on the main road. The main findings of the special right intersection analyses are listed below.

- As a category, the special right Y-intersection was found to have an overall average accident rate below that for all three-legged intersections. Special right Y-intersections do have a higher portion of severe accidents and a higher severe accident rate than all three-legged intersections taken together, but the special right Y-sites are similar in these respects to other curved Y-intersections.

- Taken as a group, special right Y-sites have a head-on accident rate that is 22% lower than for all three-legged intersections taken together. In urban areas the head-on accident rate of special right Y-intersections is 42% lower than the aggregate rate for head-on accidents at urban three-legged intersections. Furthermore, the rate for the special right Y-intersections is either significantly lower or similar to that of the other urban categories of Y's.

Y-Intersections

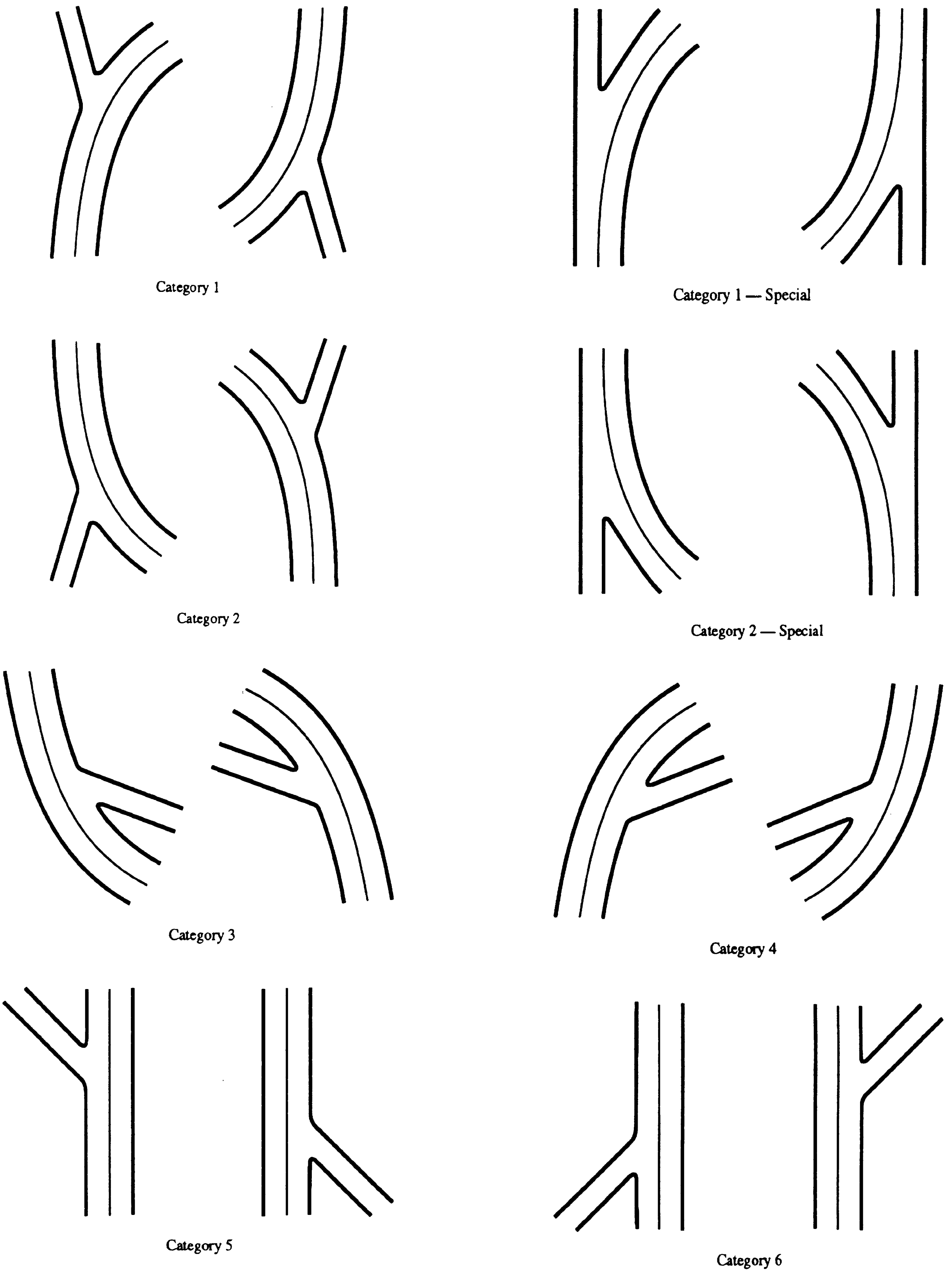

Figure 5 - Categories of Y-Intersections for Michigan Trunkline Analysis

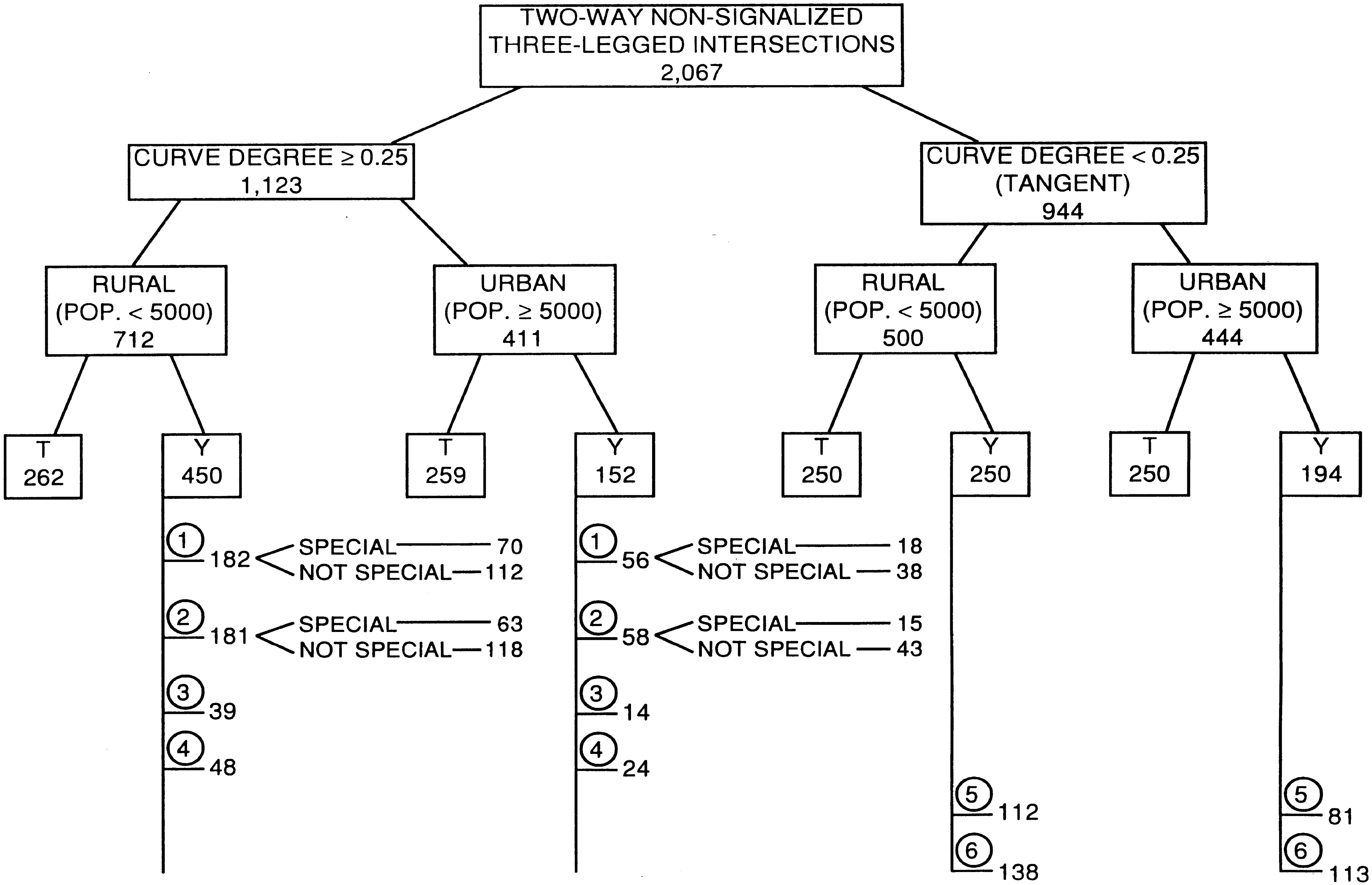

Figure 6 - Sample by Categories of Y

- In rural areas the rate of head-on collisions at special right Y-intersections is 14% higher than that for all rural three-legged intersections. However, it is not significantly different than the rate for head-on collisions at the other categories of rural Y-intersections.

- When severity of accidents was examined, it was found that when head-on accidents do occur at special right Y-intersections, they tend to be more severe than head-on collisions at other types of Y-intersections but similar to other types of curved Y-intersections.

- The special right Y-sites were found to have a high rate of run-off-road accidents. The rate for run-off-road accidents for special right Y-intersections is 53% higher than that for all three-legged intersections. This is entirely driven by the rural sites because among the urban sites, special right Y's have a rate for run-off-road collisions that is slightly lower than the aggregate.

- The rate of run-off-road accidents is also high for fatal and injury accidents, probably because of the high travel speeds associated with these predominantly rural sites. Further investigations showed that the higher rates of run-off-road accidents held only for volumes below 5,000 ADT. At volumes between 5,000 and 10,000 ADT the rate was similar to the aggregate for all three-legged intersections, and at volumes above 10,000 ADT, the rate was 20% below the aggregate.

Analysis of Special Y-Sites

Special Y-sites in the MDOT trunkline file were further investigated. The special Y-sites consisted of all sites where the main road curved either to the right or left and the side road continued on the tangent. In addition to the 88 special right Y-sites there were 78 special left sites.

Police accident reports for all the accidents at the 166 special right and left Y-intersections for 1991 were reviewed. There were 59 accidents that did not involve animals and for which the location information was correct. The level of contribution to the occurrence of the accident made by the Y geometry, the curve, and the road surface was assessed during the review. The type of accident, directions of travel, light conditions, and whether or not alcohol was involved were also noted. The difference between the contribution or association of these factors at special right and left Y-sites was tested.

Of the accidents at the special Y-intersections, almost half were single-vehicle accidents involving loss of control. Approximately 20% involved collisions of vehicles on the side road only. About 10% involved a vehicle on the side road failing to yield the right-of-way to a vehicle on the major road, 8.5%, involved vehicles traveling the same direction on the main road, and 5% involved vehicles travelling in opposite directions on the main road.

The presence of the Y-intersection was found to definitely contribute to the accident in only 12% of the cases, possibly in 42% of the cases, and definitely not in 46% of the cases.

The curve was found to be a definite contributing factor in 41% of the accidents, possibly in 22%, and definitely not in 37% of the cases. The road surface definitely contributed to 25% of the cases, possibly contributed in 14%, and did not contribute in 61% of the cases.

A disproportionate number of these accidents occurred at night and involved alcohol. Statistical tests indicate that there is no difference in the contributions of any of these factors to accident occurrence between right or left sites.

The results of this analysis indicate that the presence of the curve contributes to the occurrence of accidents at these sites as much as the intersection itself, indicating a strong curve effect and perhaps an interactive effect of the curve and intersection. The overinvolvement of alcohol in these accidents suggests that impaired drivers in particular cannot negotiate this geometry.

As part of this research, 53 special Y-sites were visited by a field crew. The crew recorded information about the traffic control, sight distance, signing, pavement markings, and delineation of each site, photographed the intersection, and observed driver behavior.

The field crew recorded their perceptions of continuity of the main road onto the side road. They looked for the optical illusion of the perceptual trap by checking for continuations of the roadway, tree lines, fence lines, utility poles, and pavement contrast. Overall, they found that the centerlines and edgelines clearly defined the curve of the main road and the contrast in pavements and markings between the main and side roads minimized the perception of continuity. Their observations stress the importance of the edgelines and centerline in identifying the main path.

To see if the perceptual trap hypothesis was apparent in the accident rates at special Y-sites, the 53 intersections with data on pavement type and road markings were divided into three categories based on pavement type on the side road and whether there was contrast between the two roads in terms of markings. It was expected that the likelihood of appearing as a perceptual trap should increase from gravel/contrast sites to paved/contrast sites to paved/no contrast sites and that a similar increase in accident rate might be observed.

Rates were calculated for special right and special left Y-intersections, both separately and combined, and rates were also calculated according to accident severity and type. Most of the analyses showed no relation between accident rate and degree of perceptual trap potential, therefore providing no support for the perceptual trap hypothesis.

The field crew also noted whether drivers proceeding from the major road to the minor road sites used their turn signal. It is speculated that drivers using their signals are aware that they are making a turn. At special right Y-intersections, drivers commonly signalled their intent to turn left onto the minor road, except at sites with a flasher or where an exclusive lane was available for continuing on the tangent. In contrast, drivers typically did not signal when turning right onto the minor road at special left Y-intersections. When proceeding from the minor road to the major road at special right intersections, drivers tended not to signal when continuing on a tangent onto the major road but often signalled when turning left onto the major road. About 60% of the drivers proceeding from a minor road onto a major road in either direction at the special left sites signalled. It appears that when drivers are proceeding onto another road without crossing the path of the other stream of traffic, they do not signal. However, if they are crossing the opposing traffic's path, they signal.

The Questions Revisited

The review of the case studies of severe accidents at special right Y-intersections led to a series of questions at the beginning of this research. These questions are now revisited in light of the findings of this research.

1. Do drivers approaching the intersection with the intent of going onto the minor road believe that they have the right-of-way? Is there something inherent about these special Y-intersections that leads drivers to assume that they have the right-of-way?

The literature review found that the particular type of geometry of the special Y-intersection is used by human factors psychologists as a classic example of a perceptual trap, i.e., a visual optical illusion. If, in fact, drivers perceive the side road as a continuation of the main path, then it can be argued that there is something inherent about these intersections which leads drivers to believe that they have the right-of-way.

Although no direct studies of driver perceptions were conducted in this research, the field observations of road continuity and signalling patterns, as well as the analysis of pavement differences, do not support the argument that drivers proceeding onto the minor road from the major road at special right Y's believe they have the right-of-way.

2. Do the special right Y-intersections have more head-on accidents than other three-legged intersections?

The findings of this research indicate that the special right Y-intersection does not exhibit a uniquely high level of head-on accidents relative to other types of three-legged intersections. However, when head-on collisions occur, there is a higher likelihood of a severe accident than there is at other types of three-legged intersections considered together. This higher likelihood is shared by the other categories of curved Y-intersections.

3. Can single-vehicle accidents at the special Y-intersections be attributed to the curve rather than the intersection itself?

Single-vehicle accidents are typically run-off-road collisions, and the special right Y-sites were found to have a high rate of run-off-road accidents at low-volume rural intersections.

A review of police accident reports of accidents at the special Y-intersections reveal a pattern of accidents in terms of type, severity, and circumstances similar to that for low-volume, rural, horizontal curves. Examining these records for contributing factors pointed to a strong curve effect on the occurrence of these accidents

This study was not designed to quantify the contributions of the curve and intersection to single-vehicle accidents at special Y-intersections. A different study design that compares accident experience at curved road sections with and without intersections would have to be carried out. However, the analyses carried out in the present effort indicate a strong effect of the curve and perhaps an interaction of the curve and intersection on the occurrence of run-off-road accidents at these sites.

4. Do drivers, unaccustomed to encountering oncoming traffic at the special right Y-sites in low-volume environments, simply forget to look for oncoming traffic?

Whether or not drivers look for oncoming traffic in low-volume environments cannot be directly answered from the analyses carried out in this study. A study that compares driver inattention in different driving environments would need to be carried out to respond to this question.

5. Are drivers genuinely confused by the geometry of the special right Y-intersection?

Again this question cannot be directly answered from the studies conducted in this research. However, if confusion at special right Y-intersections were a common problem, we would expect the accident experience at these intersections to differ significantly from other curved Y-intersections. That it does not suggests that driver confusion is not a widespread problem. In the review of police accident records, it was found that a disproportionate percentage of the accidents at special Y-intersections occurred at night and involved alcohol. Thus, it is possible that the geometry of the special Y-intersection is confusing to an impaired driver, although it is difficult to separate the effects of the curve from the effects of the intersection in this case.

6. Are the accidents reviewed in these cases typical of accidents at special right Y-intersections, or are these rare occurrences?

Most of the accidents reviewed in the case studies were severe or fatal head-on collisions. This analysis found that only 3% of all the accidents at the special right Y-intersections on the Michigan state trunkline roads are head-ons that result in a severe or fatal injury. Therefore, these accidents cannot be considered typical of accidents at the special right Y-intersections and are rare occurrences.

Implications for Countermeasure Program

The findings of this research show that the special right Y-intersection does not exhibit unusual or unique accident patterns relative to other three-legged intersections. The results indicate that the special right Y-intersection should be treated as a member of the set of curved Y-intersections in the selection and prioritizing of sites for safety improvement programs. The exception to this is the set of special right Y-intersections in low-volume, rural areas, where the rate of severe run-off-the-road accidents is particularly high. These sites should be grouped together with rural horizontal curves in the development of treatment priorities.

Identifying Problem Locations

Membership in the class of special right Y-intersections is not sufficient for an intersection to be a candidate for remedial action. Since these intersections should be considered together with all curved Y-intersections, any special right Y-intersection that has accident characteristics worse than the average curved Y-intersection should be considered as a possible candidate for safety improvement. In particular, the rates for total accidents, head-on accidents, and run-off-road accidents per vehicle volume should be considered. Since sites with very few accidents but low traffic volumes can exhibit high rates relative to traffic volume, consideration should also be given to the number of accidents at a site over time. Therefore, a process for identifying special right Y-intersections for possible safety improvements should also check if the number of accidents per year is greater than that of an average curved Y-intersection.

The following table shows the average accident rates for curved Y-intersections for both rural and urban areas that can serve as threshold values for identifying problem special right Y-sites.

Table 2 - Threshold Rates for Identifying Problem Special Right Y-Sites

Accident Rate per 100 Million Vehicles	Rural	Urban
Total Accidents	37.5	34.3
Head-On Accidents	7.7	8.8
Run-Off-Road Accidents	13.0	7.2
Number of Accidents per Site per Year	0.5	1.1

Countermeasures

From the review of policies toward Y-intersections and treatments for the special right Y-intersection, it is quite clear that the modification of the intersection to a T-configuration is the most highly recommended treatment for any problem Y-intersection. However, other types of treatments may be applicable depending on the accident pattern at the site.

Urban Areas

Special right Y-intersections in urban areas that exceed the accident rate criteria listed in Table 2 should be quite rare. As indicated earlier, the category of special right Y-intersections has lower accident rates in urban areas than other types of curved Y-intersections. However, it is possible that changes in land development increased traffic, altered the traffic patterns, and increased accidents at a location that did not previously exhibit safety problems.

The selection of a countermeasure and its design is extremely site specific and should address the problems identified in the review of the accident experience. For urban areas the following three types of countermeasures are applicable: reconstruction to a T, channelization, signalization, or some combinations of these. It should be noted that curved urban T-intersections have higher accident rates than curved Y-intersections for unsignalized intersections with two-way traffic on all legs. Thus, the redesign should not be a simple conversion to a T, but should be used together with channelization or signalization.

Rural Areas

Sites in rural areas that exceed the rural threshold rates should be candidates in a safety improvement program. An investigation of the accident patterns should precede any decision.

Overall Accident Rate Exceeded

If the overall accident rate threshold is exceeded, the prevailing accident type should be identified to select the appropriate countermeasure. For example:

If the prevailing accident type is a rear-end collision between vehicles on the main road, the treatment would be to provide a passing opportunity for through traffic. This could be accomplished with a fly-by lane (passing blister) or left-turn lane at the intersection. If the intersection is modified to a T, the opportunity for passing left-turning vehicles should also be provided.

If the prevailing accident type is a rear-end accident on the side road, the site should be checked for problems with visibility. Specifically, it may be difficult for drivers on the side road to see traffic approaching from the left on the main road. If that is the case, the best treatment for this pattern of accidents would be to modify the intersection to a T.

If the prevailing accident pattern features collisions between vehicles leaving the side road and vehicles on the main road, visibility and the difficulty of seeing oncoming vehicles on the main road should be reviewed. The best treatment for this situation would be to modify the intersection to a T. A flasher could be considered as an alternative treatment or as an interim measure. However, visibility, line of sight, and traffic volumes have to be considered carefully before the flasher is used.

Head-On Accident Threshold Exceeded

If the head-on accident threshold is exceeded, the signs and pavement markings at the site should be reviewed. If the signs and pavement markings are below MUTCD standards or in poor condition they should be improved. However, this study has found that small upgrades in signs have not had an effect on accidents at the sites that are already signed. Therefore, in most cases where the head-on collision threshold is exceeded, the intersection should be reconstructed to a T.

Run-off-Road Threshold

The threshold for run-off-road accidents given in Table 2 applies to sites with volumes over 5,000 ADT. For sites with volumes below 5,000 ADT the special right Y-sites should be grouped together with horizontal curves and the criteria used to select candidates for improvement from that set of road segments should be applied.

Run-off-road accidents at curved sites usually occur because the vehicle is travelling at speeds too fast for the curve. Signs and pavement markings that warn the driver of an upcoming curve, provide a speed advisory, and delineate the curve and guide the vehicle through it are standard treatments of such sites. Before any other treatments are considered a review of the signs and pavement markings should be made and brought up to MUTCD standards, if found to be lacking.

This study found that the rate of run-off-road accidents at curved T-sites was lower than for special right Y-intersections for all volumes categories. Furthermore, these accidents tended to be less severe at the curved T-sites than at the special right Y-sites. However, the curvature at the Y-sites tended to be greater than at the T-sites. This suggests that at sites with high rates of run-off-road accidents there may be safety benefits in modifying the special right Y-sites to T's, but the horizontal curve should also be modified in the reconstruction.

This research also found that a disproportionate percent of run-off-road accidents at special Y-intersections involve alcohol. Policy type countermeasures intended to remove impaired drivers from the road, especially in rural areas, would contribute to the reduction of this type of accident.

Routine Maintenance

The various findings about accident risks at special Y-intersections are based on data from sites with existing signs and pavement markings. The field studies and photolog review of the special Y-intersections conducted as part of this research found the signing and pavement markings to be in compliance with the MUTCD. Curves were marked with advance-warning signs and speed advisories, when needed. Chevrons and target arrows were used on more severe curves. The side roads were controlled with stop signs, usually preceded by stop-ahead signs. The pavements were marked with centerlines and edgelines.

The observations from the field studies indicate that the special Y-sites do not appear as perceptual traps because the pavement markings provide guidance as to the location of the main path. Good pavement markings counter the perceptual trap illusion. Good signing and pavement marking should not be considered as countermeasures at the special right Y-sites but rather as an integral part of the basic road system. They are essential for the operation of these intersections and must be maintained in good condition.

Conclusion

This study has examined the special Y-intersection, where the main road curves to the right and the side road continues on a tangent, from many perspectives. The severe head-on accidents at these sites which led to this research were not found to be typical of the accident experience at such sites. In terms of accident patterns, this special type of Y-intersection is similar to other types of Y-intersections on curves. Thus, the membership of an intersection in the set of Y-intersections where the main road curves to the right and the side road continues on a tangent is not sufficient to mark a site for safety improvements. The criteria by which these sites are identified for safety improvements should be the same as those applied to all curved Y-intersections. However, even if the special right Y-sites do not exhibit safety problems it is very important that the signing, centerline, and pavement edgeline delineation be maintained in good condition.