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CHAPTER FIFTY-FIVE

GEOMETRIC DESIGN OF EXISTING NON-FREEWAY (3R)

55-1.0 INTRODUCTION

Section 40-6.0 identifies project scopes of work as follows:

1. new construction;
2. complete reconstruction, freeway;
3. partial reconstruction, freeway (4R);
4. reconstruction, non-freeway (4R);
5. 3R project,non-freeway;
6. 3R project ,freeway;
7. partial 3R project, non-freeway;
8. high-accident location improvement, non-freeway; and
9. traffic-control-devices project.

Chapter Fifty-three provides tables of geometric design criteria which apply to a new construction or reconstruction project. Chapters Forty through Fifty-two provide design concepts and criteria which are directly applicable to new construction or reconstruction. For this type of project, the designer has the liberty of designing the highway to satisfy the most desirable and stringent criteria practical.

The geometric design of a project on an existing highway is viewed from a different perspective. This type of project is often initiated for reasons other than geometric design deficiencies (e.g., pavement deterioration, bridge replacement), and it often must be designed within restrictive right of way, and financial or environmental constraints. Therefore, the design criteria for new construction are often not attainable without major and, frequently, unacceptable adverse impacts. At the same time, however, the Department must use the opportunity to make cost-effective, practical improvements to the geometric design of an existing highway or street.

For these reasons, INDOT has adopted different limits for geometric design criteria for a project on an existing highway which are often lower than the values for new construction. The criteria for an existing highway are based on a sound, engineering assessment of the underlying principles behind geometric design and on how the criteria for new construction can be modified to apply to an existing highway.

This chapter provides the Department's criteria for a 3R non-freeway project. These criteria balance the many competing and often conflicting objectives. The objectives include improving an existing highway, minimizing the adverse impacts of highway construction on an existing highway, and improving the greatest longitudinal distance within the available funds for capital improvements. Where the 3R project scope of work is selected, costly work (e.g., bridge reconstruction or replacement, alignment improvements), which has a long service life and can be incorporated into a future 4R project, should desirably be constructed to satisfy 4R design criteria as part of the 3R project.

55-2.0 GENERAL REQUIREMENTS

55-2.01 Applicability

55-2.01(01) 3R Scope-of-Work Definition

A 3R project (rehabilitation, restoration, and resurfacing) on an existing non-freeway is intended to extend the service life of the existing facility and to enhance highway safety. A 3R project should make cost-effective improvements to the existing geometrics, where practical. This type of work on the mainline or at an intersection is on the existing alignment. Minimal right-of-way acquisition is required. Improvements for a 3R non-freeway project can include a combination of the following:

1. pavement resurfacing or rehabilitation or a limited amount of pavement reconstruction (30% or less of the traveled-way area);
2. bridge rehabilitation or replacement;
3. lane or shoulder widening;
4. upgrading the structural strength of shoulders;
5. flattening an occasional horizontal or vertical curve;
6. adjustments to the roadside clear zone;
7. flattening side slopes;
8. converting an existing median to a 2-way left-turn lane (TWLTL);
9. adding a climbing lane;

10. converting an uncurbed urban street into a curbed street;

11. revising the location, spacing, or design of existing drives along the mainline;

12. adding or removing a parking lane;

13. bridge widening and associated substructure work to accommodate the widening;

14. bridge-railing upgrading or replacement;

15. bridge-deck overlay;

16. work to preserve the bridge substructure;

17. adding a sidewalk;

18. relocating utility poles;

19. upgrading guardrail or other safety appurtenances to satisfy certain criteria;

20. other geometric or safety improvements to an existing bridge within the project limits;

21. drainage improvements;

22. increasing vertical clearance at an underpass;

23. intersection improvement (e.g., adding turn lanes, flattening turning radii, channelization, sight-distance improvements, etc.);

24. adding a new or upgrading an existing traffic signal; or

25. other spot improvements.

Specifically related to the level of pavement improvement, the following definitions apply.

1. Resurfacing. Resurfacing consists of the placement of additional surface material over the existing restored or rehabilitated roadway or structure to improve serviceability or to provide additional strength.

2. Restoration or Rehabilitation. Restoration or rehabilitation is defined as work required to return the existing pavement to a condition of adequate structural support or to a condition adequate for the placement of an additional stage of construction. This may

include milling the existing pavement.

55-2.01(02) National Highway System (NHS) Project

For long-range transportation planning purposes, INDOT has evaluated the State highway system to determine which routes warrant reconstruction, or 4R work, and which routes warrant a 3R-type improvement. Figure 55-2A shows a map of the State highway system which indicates 3R and 4R routes. The following will apply to the use of Figure 55-2A for such routes on the NHS.

1. General. The factors which will determine if a project should be classified as 3R or 4R are as follows:

    a. If 70% or more of the existing pavement area of the traveled way can be retained and resurfaced, the project may be classified as 3R. If not, the project is classified as a 4R project.

    b. An assessment of the level of service (LOS) for the 10-year traffic volume projection, which is based upon the expected service life of the pavement, can be used to determine if the project is 3R or 4R.

    Other factors should also be considered when making the project scope of work determination (e.g., accident rates).

2. 4R Non-Freeway Route. The Production Management Division's Office of Environmental Services, or the local jurisdictional agency will determine the LOS for the 10-year traffic volume projection based on the discussion in Section 40-2.0. If this is LOS of D or better, it will be acceptable to design the project using the 3R geometric design criteria described in this Chapter. If the projected LOS will not satisfy LOS of D, the facility will be designed according to the criteria for new construction or reconstruction. Each bridge replacement, bridge deck replacement, or bridge-widening should be designed to satisfy new construction, or 4R, criteria.

3. 3R Non-Freeway Route. The project will be designed according to the 3R geometric design criteria described in this Chapter. However, consideration could be given to using the 4R criteria.

4. Combination Project. Where a project will include both 3R and 4R work, the overall project scope-of-work classification should be based on the predominant type of work.

For example, a 6-mi resurfacing project which includes the replacement of one of the mainline bridges to 4R criteria will be classified as a 3R project, unless the bridge is considered to be a major structure and its replacement cost is equal to or greater than that of the 3R roadway work.

55-2.01(03) Non-NHS Project

The project scope-of-work definitions in Section 40-6.01 and Figure 55-2A, 3R/4R Systems, are intended only as general guidance for a non-NHS project. The decision on classifying a project that is not on the NHS should be made based on the future plans of the jurisdictional highway agency for the entire road between logical termini for the foreseeable future (20 years). All future plans for a road must consider current and projected traffic volumes, anticipated land use, and accident experience. The following provides examples of applying this concept to a non-NHS project.

1. Example 1. Approximately 60% of the pavement on a 6-mi section of a county road will be replaced. The remainder of the pavement is in reasonably good condition and only requires milling and resurfacing. The 6-mi section is part of a 30-mi county road which is the main highway between two small towns. The existing road has a LOS of A, and it is anticipated to provide a LOS of B based on 20-year projected traffic volume. There is no adverse accident experience for the past three years. Based on this information, a highway agency could decide to designate the 3R classification and construct the road to 3R design criteria. This is acceptable even though more than 30% of the pavement is being completely replaced.

2. Example 2. Approximately 40% of the pavement on a 6-mi section of county road will be replaced. The remainder of the segment will be resurfaced. This segment of road is part of a 25-mi county road which connects two small towns. This county road is located approximately 20 mi from a major metropolitan area. It is anticipated that, within the next 20 years, there will be considerable residential and commercial development adjacent to this stretch of county road because of its proximity to the rapidly expanding metropolitan area. The current LOS is B, but projected traffic volume indicates that the LOS will drop to D in 10 years and to F in 20 years. For this situation, the highway agency has two options. It can design the project to 3R criteria for the present and, then, undertake a 4R project in 10 years when the pavement will likely be in need of major work. Its second option is to construct the project to 4R criteria now to satisfy future traffic demands.

3. Example 3. A 6-mi section of highway, which is located on INDOT's 3R highway system, requires complete pavement replacement because of poor drainage. The Central Office has rechecked the status of this highway with the district office and verified that there are no plans for work on the remainder of this route in the future (20 years) except for 3R-type work. The current LOS is B, and it is anticipated to remain at B for the next

20 years. There is no adverse accident experience and no anticipated major land development along the route. INDOT can decide to only construct the project to 3R design criteria, though all of the pavement is being replaced.

4. Example 4. A 200-ft-long bridge on the State's 3R system requires complete replacement. There are sharp horizontal curves on each end of the bridge where numerous accidents have occurred during the last three years. It has been decided to correct the poor alignment on the bridge approaches and to construct the approaches and bridge on a new location. The total length of the project is 1.5 mi. The Central Office has discussed the status of this road with the district office and both agreed that it should remain on the 3R system. The current LOS is B, and it is estimated that the LOS will be C in 20 years. There are no plans except to perform 3R-type work to the remainder of the road for the future (20 years). For this situation, INDOT can decide to construct the entire project to 3R design criteria.

5. Example 5. A 6-mi segment of a route on INDOT's 3R system requires replacing 20% of the pavement and resurfacing the remaining 80%. The current LOS is D and will deteriorate to E in 5 years. There is rapid residential, commercial, and industrial development in the area. Both the Central and district offices agree that the entire route was properly classified as a 3R route. However, this one 6-mi segment is an exception because rapid growth adjacent to this segment is expected to occur. The appropriate solution in this situation is to upgrade the facility to accommodate anticipated traffic demand for the next 20 years and to design the project to 4R design criteria.

55-2.01(04) Procedures

For an INDOT project, the project scope of work is selected based on the following procedure.

1. The district office initially identifies the project scope.

2. The project is programmed based on the project scope determined by the district.

3. The Production Management Division's Office of Environmental Services will make the final decision on the scope of work. However, for an Interstate-system project which has an estimated construction cost exceeding $1 million, FHWA will meet with representatives of the Office of Environmental Services to cooperatively agree on the project classification. This will occur as early in the project-scoping process as possible so that FHWA may have input on each project which is classified as 4R. The meeting will be held as soon as an initial concept for the project design has been developed.

4. The Production Management Division, during project design, may re-evaluate the project

scope and request the Office of Environmental Services to modify the scope of work.

For a Federal-aid project not on the State highway system, the project scope of work determination will be based on the future plans of the local agency for improvements to its local road or street system. The philosophy described in Section 55-2.01(02) Item 2 for a 4R non-freeway State route should also be applied to a local project. The local agency must submit a letter to the Planning Division to document the local agency's plans on that facility in the foreseeable future. If the project is on the Interstate system and the estimated construction costs exceed $1 million, the Planning Division will schedule a meeting with the local agency and the FHWA to determine the project's classification (3R or 4R). This meeting should occur early in the scoping process so that the FHWA may have input on each project that is classified as 4R.

55-2.02 Background

The 1976 Federal-aid Highway Act made it possible for the Department and local agencies to use Federal funds to extend the service life for the maximum number of centerline miles possible for the total highway system. On June 10, 1982, the FHWA issued its Final Rule entitled *Design Standards for Highways; Resurfacing, Restoration and Rehabilitation of Streets and Highways Other Than Freeways*. This rule modified 23CFR Part 625.4 to adopt a flexible approach to the geometric design of a 3R non-freeway project. Part 625.4 was modified again on March 31, 1983, to explicitly state that one objective of a 3R project is to enhance highway safety. In the rule, FHWA determined that it was not practical to adopt 3R design criteria for nationwide application. Instead, each State was permitted to develop its own criteria or procedures for the design of a 3R project. This approach is in contrast to the application of criteria for new construction and reconstruction, for which the AASHTO *A Policy on Geometric Design of Highways and Streets* provides nationwide criteria for application. The flexible approach for 3R work permits Indiana to tailor its design criteria for its 3R program consistent with the conditions which prevail within the State. A highway for which geometrics were established some time ago is still capable of providing useful transportation service. Minor improvements will most often make such a highway serviceable for many more years.

In 1987, the Transportation Research Board (TRB) published Special Report 214, *SR214 Designing Safer Roads; Practices for Resurfacing, Restoration and Rehabilitation*. The objective of the TRB study was to examine the safety cost-effectiveness of highway geometric design criteria and to recommend minimum design criteria for a 3R project on a non-freeway. See *SR214* for more discussion.

INDOT has developed its own criteria for the geometric design of a 3R non-freeway project. Its objectives in developing these criteria may be summarized as follows:

1. extend the service life of the existing facility and to return its features to a condition of

structural or functional adequacy;

2. incorporate highway safety enhancements, where judged to be cost effective; and

3. incorporate cost-effective, practical improvements to the geometric design of the existing facility.

55-2.03 Geometric-Design Approach

The Department's approach to the geometric design of a 3R non-freeway project is to adopt, where justifiable, a revised set of numerical criteria. The design criteria throughout the other *Manual* chapters provide the frame of reference for the 3R criteria. The following summarizes the approach which has been used.

1. Design Speed. As discussed in Section 55-4.01, the design speed will be based on the existing posted or legal speed limit. The selected 3R design speed will then be used to evaluate all geometric design features of the existing highway which are based on speed (e.g., horizontal and vertical curvature).

2. Cross-Section Width. The criteria shown in Chapter Fifty-three for new construction or reconstruction have been evaluated relative to the constraints of a 3R project. Where justifiable, the cross-section width criteria have been reduced. Where a range of values is provided in the Chapter Fifty-three figures, the upper values have been incorporated into the 3R criteria to provide a desirable objective. This provides an expanded range of acceptable values for application on a 3R project. See Section 55-4.05 for additional discussion on cross-section width.

3. Other Design Criteria. Part V includes other proper geometric design techniques. These criteria are obviously applicable to new construction or reconstruction. For a 3R project, these criteria have been evaluated and a judgment has been made on their proper application to a 3R project. Unless stated otherwise in this Chapter, the criteria in other chapters applicable to a 3R project should be incorporated if practical.

4. Evaluation. Available data, e.g., accident experience, should be evaluated when determining the geometric design of a 3R project. The following section discusses 3R project evaluation in more detail.

55-2.04 3R Project Evaluation

Sections 55-3.0 to 55-7.0 provide the specific geometric-design and roadside-safety criteria which will be used to determine the design of a 3R project. In addition, other factors must be considered in a 3R project design. Applicable evaluations should be conducted as may be deemed necessary. These evaluations are discussed below.

1. Accident Experience. The historical accident data within the project limits will be evaluated. This is the most critical element of 3R project evaluation to determine the appropriate level of geometric and safety improvement. Accident data is available from the Planning Division's Office of Safety and Mobility. Section 55-8.0 further describes the Department's accident-analysis procedures.

2. Existing Geometrics. The designer will review the as-built plans and combine this review with the field review and field survey to determine the existing geometrics within the project limits. This includes lane and shoulder widths, horizontal and vertical alignment, intersection geometrics, and roadside-safety design.

3. Speed Studies. The designer will make the initial determination if a speed study is required for project design. The speed study should be conducted before the field review. The speed study will be conducted by the district for an INDOT project, or by the local public agency or its consultant for a local-agency project.

4. Physical Constraints. The physical constraints within the limits of the 3R project will often determine what geometric improvements are practical and cost-effective. These include topography, adjacent development, available right-of-way, utilities, and environmental constraints (e.g., wetlands).

5. Field Review. The designer will conduct a thorough field review of the proposed 3R project. Other personnel should attend the field review as appropriate, including personnel from traffic, maintenance, construction, local agencies, etc. The objective of the field review should be to identify potential safety hazards and potential safety improvements to the facility.

6. Pavement Condition. A 3R project is sometimes programmed because of a significant deterioration of the existing pavement structure, including subbase, base, and surface courses. The extent of deterioration will determine the necessary level of pavement improvements. This decision will also influence the extent of practical geometric improvements. For a road to be eligible for resurfacing, the pavement should exhibit one or more of the following conditions such that a timely resurfacing is needed to prevent more serious deterioration.

    a. alligator cracking.
    b. bleeding.
    c. block (cracking).

d. bumps (upheaval).
e. corrugation.
f. depression and rutting.
g. edge cracking.
h. longitudinal and transverse cracking.
i. patching or utility cut.
j. polished aggregate;
k. potholes.
l. slippage cracking; or
m. weathering and raveling.

The proposed pavement improvement will be based on the design-year traffic volume. The design year is 10 years after construction for a resurface project, or 20 years after construction for a pavement-replacement project. The pavement surface will be designed to incorporate skid resistance.

7. <u>Structures</u>. A 3R project may include bridges and culverts within the project limits or a 3R project may be a bridge improvement. Each bridge or culvert should be evaluated for possible structural improvements which may include the following:

   a. increasing the structural loading capacity;
   b. improving the roadside safety (e.g., upgrading the bridge railings);
   c. improving the horizontal and vertical alignments;
   d. widening the structure; or
   e. increasing the facility's hydraulic capacity.

8. <u>Geometric Design of Adjacent Highway Sections</u>. The designer should examine the geometric features and operating speeds of highway sections adjacent to the 3R project. This will include investigating whether or not highway improvements are in the planning stages. The 3R project should provide design continuity with the adjacent sections. This involves a consideration of factors such as driver expectancy, geometric design consistency, and proper transitions between sections of different geometric designs.

9. <u>Early Coordination for Right-of-Way Acquisition or Utility Accomodation</u>. Field reviews and accident or speed studies may indicate the need for selective safety improvements which will require right-of-way purchases. Right-of-way acquisition should be initiated as early as feasible.

   Utility relocation and accommodation is frequently encountered. Therefore, early coordination with utility companies is essential.

10. <u>Traffic Operations</u>. The designer should evaluate existing traffic operations to determine

where improvements can be reasonably implemented (e.g., adding turn lane, removing a signal, adding additional lane through an intersection). The designer should also review the effect construction will have on traffic operations. This may require reprogramming signals, implementing a phased construction plan, etc. Part VIII provides additional information on traffic management through a construction zone.

11. Maintenance and Protection of Traffic. A 3R project can only occur on an existing highway. Therefore, maintenance and protection of traffic during construction will be an important consideration in 3R project development. See Part VIII for criteria on the design of the work zone for traffic accommodation.

12. Traffic-Control Devices. All signing and pavement markings should be in accordance with Part VII and the *Manual on Uniform Traffic Control Devices* (MUTCD). The district traffic office or the local agency is responsible for selecting and locating the traffic-control devices. However, the designer should work with the proper authority to identify possible geometric and safety deficiencies which will remain in place (i.e., no improvement will be made). These may include the following:

    a. narrow bridge;
    b. horizontal or vertical curve which does not satisfy the 3R criteria; or
    c. roadside hazard within the obstruction-free zone.

    The proper authority will then determine if additional signing, traffic-control devices, or delineation treatments are warranted.

13. Documentation of Design Process. The designer should prepare an Engineer's Report for an INDOT-route project or a Safety and Design Report for a local-agency project. The report should include the following:

    a. existing geometric and roadside features, traffic volume and speed, and accident history;

    b. applicable minimum design criteria;

    c. specific safety problems or concerns raised by a review of accident data by a field inspection or by the public;

    d. design options for correcting safety problems and the cost, safety, or other relevant impacts of these options;

    e. proposed exceptions to applicable design criteria and the rationale to support the exceptions; and

f. the recommended design proposal.

The designer must also prepare a list of potential design exceptions, which must be fully documented in accordance with Section 40-8.0.

55-3.0 GEOMETRIC DESIGN CRITERIA

Figures 55-3A through 55-3H provide the Department's criteria for the design of a 3R non-freeway project, either in a rural or urban area.

The criteria are assigned the figure numbers and are titled as follows:

55-3A	Geometric Design Criteria for Rural Arterial, 3R Project
55-3B	Geometric Design Criteria for Rural Collector, State Route, 3R Project
55-3C	Geometric Design Criteria for Rural Collector, Local-Agency Route, 3R Project
55-3D	Geometric Design Criteria for Rural Local Road, 3R Project
55-3E	Geometric Design Criteria for Urban Arterial, Four or More Lanes, 3R Project
55-3F	Geometric Design Criteria for Urban Arterial, Two Lanes, 3R Project
55-3G	Geometric Design Criteria for Urban Collector, 3R Project
55-3H	Geometric Design Criteria for Urban Local Street, 3R Project

The designer should consider the following in the use of the figures.

1. Project Scope of Work. The Department has adopted separate criteria for the geometric design of a new construction or reconstruction project. See Chapter Fifty-three. Chapter Forty provides definitions for a non-freeway project scope of work, which will determine which set of criteria to use for project design.

2. Functional Classification. The selection of design values depends on the functional classification of the highway facility. This is discussed in Section 40-1.01. Functional classification maps for all public roads in the State are available from the Planning Division.

3. Urban Design Subcategories. Within an urbanized or urban area, the selection of design values depends on the design subcategory of the facility. Separate criteria are provided for suburban, intermediate, and built-up subcategories. These classifications are defined as follows.

    a. Suburban. This type of area is located at the fringe of an urbanized or small urban area. The predominant character of the surrounding environment is residential, but it may include a considerable number of commercial establishments, especially strip development along a suburban arterial. There may also be a few industrial parks. On a suburban road or street, motorists have a significant degree of freedom but, nonetheless, they must also devote some of their attention to entering and exiting vehicles. Roadside development is characterized by low to moderate density. Pedestrian activity may or may not be a significant design factor. Right of way is often available for roadway improvements.

A local or collector street is located in a residential area, but may also serve a commercial area. The posted speed limit ranges between 30 and 50 mph. The majority of intersections will have stop or yield control, but there will be an occasional traffic signal. A suburban arterial will have strip commercial development and perhaps a few residential properties. The posted speed limit ranges between 35 and 55 mph. There will usually be a few signalized intersections along the arterial.

b. Intermediate. As the name implies, an intermediate area is between a suburban and a built-up area. The surrounding environment may be either residential, commercial, or industrial or a combination of these. The extent of roadside development will have a significant impact on the selected speeds of motorists. The increasing frequency of intersections is also a major control on average speeds. Pedestrian activity has now become a significant design consideration, and sidewalks and crosswalks at intersections are common. The available right of way will restrict the practical extent of roadway improvements.

A local or collector street has posted speed-limit ranging between 30 and 45 mph. The frequency of signalized intersections has increased substantially if compared to a suburban area. An arterial will have intensive commercial development along its roadside. The posted speed limit ranges between 35 and 50 mph. Such an arterial has several signalized intersections per mile.

c. Built-up. This type of area refers to the central business district within an urbanized or small urban area. The roadside development has a high density and is often commercial. However, a substantial number of roads and streets pass through a high-density environment (e.g. apartment complexes, row houses). Access to property is the primary function of the road network. Pedestrian considerations may be as important as vehicular considerations, especially at intersections. Right of way for roadway improvements is usually not available.

Because of the high density of development, the distinction between the functional classifications (local, collector, or arterial) becomes less important in considering signalization and speeds. The primary distinction among the three functional classifications is the relative traffic volumes and, therefore, the number of lanes. As many as half the intersections may be signalized. The posted speed limits ranges between 25 and 35 mph.

See Section 40-1.01 for definitions of the functional classifications.

4. Rural-Area Figures. These do not provide design criteria for sub-categories. However, there are many rural facilities which pass through relatively built-up, but unincorporated, areas. It may be inappropriate to use the rural-area design criteria. The designer may, as an option, use the suburban criteria for a functional classification (e.g., arterial) in a relatively built-up rural area. Therefore, if the area is urban in character (e.g., a densely populated area with a grid-like street system), it may be appropriate to use the urban-area design criteria, though the facility is rural. This decision will be documented in the Engineer's Report (see Chapter Seven).

5. Cross-Section Elements. Some of the cross-section elements included in a figure (e.g., sidewalk width) are not automatically warranted in the project design. The value will apply only after the decision has been made to include the element in the highway cross section.

   A 3R project should not be designed with a narrower roadway width than the existing facility. See Section 55-4.05.

6. *Indiana Design Manual* Section References. The figures are intended to provide a concise listing of design values for easy use. However, the designer should review the *Manual* section references for greater insight into the design elements.

7. Footnotes. The figures include many footnotes, which are identified by a number in parentheses, e.g., (6). The information in the footnotes is critical to the proper use of the figure.

8. Controlling Design Criteria. An asterisk indicates each controlling design criterion which, if not satisfied, requires a Level One design exception. The discussion in Section 40-8.0 on design exceptions applies equally to the geometric design of a 3R project. However, the designer will evaluate the proposed design against the criteria described in this Chapter.

55-4.0 GEOMETRIC DESIGN

55-4.01 Design Controls

55-4.01(01) Traffic-Volume Analysis

The following traffic-volume controls will apply.

1. Design Year. Pavement resurfacing should be designed using a 10-year design life. Pavement replacement and all other elements of the facility should have a design life of 20 years beyond the expected construction date.

2. Level of Service (LOS). The appropriate figure in the 55-3 series provides the desirable and minimum LOS criteria.

3. Traffic Data. The designer should obtain, from the Production Management Division's Office of Environmental Services, the traffic data necessary to determine the level of improvement. At a minimum, this will include current and future (10 and 20 years) AADT, DHV, percent of trucks and buses, turning movements at intersections, accident data for the most recent 3-year period, and known future traffic impact.

4. Capacity Analysis. The analytical techniques described in the *Highway Capacity Manual* should be used to conduct the capacity analysis.

55-4.01(02) Design Speed

The existing posted or legal speed limit will most often be selected as the design speed. More specifically, the design speed should be the highest posted speed limit or legal speed limit existing on logical sections of the roadway consistent with the expectations for that section of roadway and future improvement plans. Logical sections will be based on land use and topography. If a road is not posted, it is desirable to perform an engineering study to determine an appropriate posted speed limit.

If the facility is posted, it may be appropriate to perform an engineering study if there is sufficient reason to believe that the existing posted speed limit may change after project completion. The designer may request, and the district traffic office or local jurisdiction may determine, that a speed study within the project limits is necessary to establish a 3R design speed.

Section 40-3.02 discusses the relationship between the project design speed and the legal speed limit. The Section also provides the legal speed limits from the State statutes which apply to all public roads.

In summary, the selection of a 3R project design speed will be one of the following:

1. the existing posted speed limit;

2. the legal speed limit on a non-posted facility;

3. a revised posted speed limit or the anticipated posted speed limit on a currently non-posted facility; based on the results of a speed study; or

4. a design speed which is higher than the posted or regulatory speed limit, where deemed to be appropriate.

55-4.01(03) Adherence to Design Criteria

The discussion in Section 40-8.0 regarding design exceptions applies equally to the geometric design of a 3R project. However, the designer will evaluate the proposed design against the criteria described in this Chapter. A Level One design exception will be required where reconstructing a horizontal or vertical curve has been determined to be cost effective, but other factors would make the improvement impractical.

55-4.02 Sight Distance

The criteria described in Chapter Forty-two regarding sight distance applies equally to a 3R project. However, the application of the sight-distance criteria to each individual highway element (e.g., vertical curve) on a 3R project will differ from that applied to a new construction or reconstruction project. These are discussed at the applicable locations elsewhere in this Chapter.

55-4.03 Horizontal Alignment

Engineering judgment or a cost-effectiveness evaluation will ultimately reveal the need for improvements to the horizontal alignment. Improvements to the horizontal alignment should be considered if a specific problem is identified. Examples include the following:

1. a disproportionate run-off-the-road accident rate at a curve site;

2. a disproportionate number of multi-vehicle accidents at a curve site; or

3. the presence of an adverse accident history at an intersection within a curve.

The evaluation of potential improvements will include a consideration of traffic volume, truck volume, right-of-way and utility impacts, environmental impacts, driver expectancy, construction costs, etc.

55-4.03(01) Minimum Horizontal-Curve Radius

The designer should determine the Computed Existing Design Speed (CEDS) of the each curve radius within the 3R project limits. To determine the CEDS, the designer should determine the applicable maximum superelevation rate for the project location. For a rural highway or an urban facility where $V \geq 50$ mph, an e_{max} of 8% should be used (see Figure 43-3A). For an urban facility where $V \leq 45$ mph, an e_{max} up to 6% may be used (see Figure 43-3C). An existing horizontal curve may be retained if the conditions exist as follows:

1. the accident data does not indicate a problem at the curve site;

2. the CEDS is not more than 15 mph below the 3R design speed; and

3. the AADT is not greater than 750 vehicles per day.

The existing radius will be retained on a curve where the above conditions are satisfied (i.e., the curve need not be evaluated). However, proper signs and markings may be necessary to inform the motorist of non-conforming criteria. If the above conditions are not satisfied on an existing horizontal curve, a safety benefit/cost study (B/C) should be conducted to determine if the proposed correction will be cost effective. Chapter Fifty describes the Department's procedures for conducting a benefit/cost analysis. If the B/C ratio is less than 1.0, the existing horizontal curve may be retained. Where the B/C ratio is greater than or equal to 1.0 and it is decided to reconstruct the curve to satisfy the minimum-radius criteria, the curve should desirably be reconstructed to satisfy all horizontal-alignment requirements for new construction or reconstruction (e.g., superelevation rate, superelevation transition length, distribution of superelevation between tangent and curve). See Chapter Forty-three. If reconstruction is shown to be cost effective and it is decided not to undertake the work, it will be necessary to request a Level One design exception.

55-4.03(02) Superelevation

On a horizontal curve where the existing radius will be retained, it may be warranted to make improvements to the superelevation. The following will apply.

1. <u>General</u>. The most desirable objective is to improve the horizontal curve to satisfy all superelevation criteria shown in Section 43-3.0.

2. <u>Rate</u>. Where the CEDS is less than the design speed, the superelevation rate should be increased to provide the design speed, up to a maximum of 8% (rural) or 6% (urban).

In an urban area, it may be appropriate to remove or reduce the existing superelevation if the design speed of the revised curve will equal or exceed the project design speed (see Section 43-3.02). This may be advantageous to better satisfy the roadside development or drainage conditions, or to provide better operations at an at-grade intersection.

3. Transition-Length Distribution. The superelevation transition length will be distributed by placing 60% to 70% on the tangent and the remainder on the horizontal curve. However, where this is not practical, a reduction to a 50% to 50% distribution is acceptable.

4. Shoulder Superelevation. The travelway-to-shoulder rollover break is placed at the edge of travelway on the outside of a horizontal curve. However, where a paved shoulder of 4 ft or narrower is used, the break should occur at the outside edge of the paved shoulder.

55-4.03(03) Reverse Curves

It may be acceptable to leave reverse curves in place if the PT and PC are coincident. To determine if improvements are warranted, existing combined reverse curves should be evaluated using the criteria in Section 43-3.07, and for each individual curve, Sections 55-4.03(01) and 55-4.03(02). An evaluation of the accident history should be made for existing reverse curves (e.g., multi-vehicle accidents).

55-4.03(04) Broken-Back Curves

For existing broken-back curves, the designer should, if practical, eliminate the curves and combine them into a single, continuous horizontal curve, especially where an evaluation of the accident history indicates a problem.

55-4.03(05) Curves in Series

The alignment of a segment of a roadway often consists of a series of reverse curves or curves connected by short tangents. A succession of curves may be analyzed as a unit rather than as individual curves, applying the criteria described in Section 55-4.03(01).

1. The first substandard curve in a series should be analyzed individually as this change in alignment prepares the driver for the remaining curves in the series.

2. An intermediate curve in a series of substandard curves that is significantly worse than the others in the series should also be analyzed individually.

2. These controlling curves can be used to determine the safety or other mitigation measures to apply throughout the series.

3. Where improvements are considered to curves in a series, the effect on the series of curves as a whole should be evaluated.

55-4.03(06) Shoulder Treatment

On a facility with relatively sharp horizontal curves and truck volume greater than 500 per day, a full-structural strength shoulder should be provided on both sides of a sharp horizontal curve in place of pavement widening. The following will apply.

1. Strengthened Length. The strengthened shoulder should be available from the beginning of the superelevation transition before the curve to the end of the transition beyond the curve.

2. Asphalt Traveled Way. The pavement structure of the strengthened shoulder should match that of the traveled way.

3. Concrete Traveled Way with Asphalt Shoulder. The Office of Pavement Engineering will determine the pavement structure of the strengthened shoulder.

4. Concrete Traveled Way with Concrete Shoulder. The concrete-shoulder thickness should match that of the traveled way.

55-4.03(07) Horizontal Sight Distance

Section 43-4.0 provides criteria for determining if the applicable sight distance is available at a horizontal curve. If an existing longitudinal barrier interferes with the line of sight at a horizontal curve, the designer should review practical alternatives to alleviate the problem, such as eliminating the hazard that requires the barrier or offset the barrier further from the travel lane. If it is determined to leave the barrier in its existing location, it will be necessary to seek a design exception for the stopping sight distance.

55-4.03(08) Traffic-Control Devices

For an existing horizontal curve to remain as such, traffic-control devices that may be considered to improve motorist safety and comfort include the following:

1. signing (e.g., advance warning, chevron);
2. raised pavement markers; or
3. reflective marker posts or delineators.

Part VII and the *MUTCD* discuss the selection and installation of traffic-control devices in more detail.

55-4.04 Vertical Alignment

55-4.04(01) Grades

The appropriate figure in the 55-3 series provides the Department's criteria for maximum and minimum grades. The maximum grade is 1% steeper than that for new construction or reconstruction on a rural arterial, or 2% steeper for another type of facility. Improvements to an existing grade should be considered if a specific problem is identified (e.g., head-on accidents due to improper passing maneuvers, significant speed reduction for trucks).

55-4.04(02) Climbing Lane

The warrants for a climbing lane shown in Section 44-2.0 are also applicable to a 3R project. The following will apply to the design of a climbing lane.

1. New. The criteria shown in Section 44-2.0 should be used.

2. Existing. Desirably, the criteria shown in Section 44-2.0 should be used. However, existing lane and shoulder widths may be retained if there is no adverse accident history that can be related to the narrower width.

55-4.04(03) Crest Vertical Curve

Existing crest vertical curves will most often be incorporated into a 3R project. An existing crest vertical curve may be retained if the conditions exist as follows:

1. there is no history of accidents related to the vertical curve (e.g., rear-end accidents);

2. the crest does not hide major hazards from view such as an intersection, sharp horizontal curve, or a narrow bridge;

3. the CEDS of the existing crest (based on minimum sight distance for a passenger car) is not

more than 20 mph below the 3R-project design speed using a 2-ft object height; and

4. the design-year AADT is not greater than 1500.

If an existing crest vertical curve does not satisfy all of the criteria listed in Items 1 through 4 above, such that reconstruction may be warranted, a benefit/cost (B/C) study should be conducted to determine if the proposed correction will be cost effective. Chapter Fifty provides the Department's procedures for conducting a benefit/cost analysis. If the B/C ratio is less than 1.0, then the existing vertical curve can be retained. Where the B/C ratio is greater than or equal to 1.0 and it is decided to reconstruct the vertical curve, it should be designed using the criteria for new construction/reconstruction (see Section 44-3.0). If reconstruction is shown to be cost-effective and it is decided not to undertake the work, it will be necessary to request a Level One design exception.

55-4.04(04) Sag Vertical Curve

Section 44-3.0 provides the Department's criteria for the design of a sag vertical curve for new construction or reconstruction. These criteria are based on designing the sag to allow the vehicular headlights to illuminate the pavement for a distance equal to the stopping sight distance for a passenger car. An existing sag vertical curve may be evaluated using the comfort criteria shown in Figure 55-4A, *K* Value for Sag Vertical Curve (Comfort Criteria - 3R Project).

The following options for evaluating a sag vertical curve are shown below in order from the most desirable to the least desirable.

1. Improve the sag vertical curve to the new construction or reconstruction criteria shown in Section 44-3.0 if it is cost effective to do so.

2. Improve the sag vertical curve to be in accordance with the *K* value for comfort criteria shown in Figure 55-4A. An existing sag vertical curve that can be improved by wedge and level up to 18 in. depth to be in accordance with the comfort criteria shown in Figure 55-4A, may be retained.

3. Reconstruct the sag vertical curve to an improved level, but not in full accordance with the comfort criteria.

4. Retain the existing sag vertical curve though it is not in accordance with the comfort criteria.

If an existing sag vertical curve does not satisfy the comfort criteria shown in Figure 55-4A, or there is a history of accidents related to the curve such that reconstruction may be warranted, a benefit/cost study should be conducted to determine if the proposed correction will be cost effective. Chapter Fifty provides the Department's procedures for conducting a benefit/cost analysis. If improvement in accordance with Section 44-3.0 is shown to be cost-effective and it is decided not to undertake the work, it will be necessary to request a Level One design exception.

55-4.04(05) Curves in Series

The vertical alignment of a segment of a roadway can consist of a series of sag and crest vertical curves or vertical curves connected by short grades. A succession of vertical curves may be analyzed as a unit rather than as individual curves, applying the criteria in Sections 55-4.04(03) and 55-4.04(04). Analysis procedures similar to Section 55-4.03(05) Items 1 through 4 should be followed.

55-4.04(06) Angle Point

It is acceptable to retain an existing angle point, with no vertical curve, of 0.5% algebraic difference for a crest situation, or 1.0% algebraic difference for a sag situation.

55-4.05 Cross-Section Elements

Chapters Forty-five and Fifty-three provide the Department's criteria for cross-section elements for a new construction or reconstruction project. The figures in Section 55-3.0 provide the cross-section criteria for a 3R project. The criteria were established as follows:

1. Upper Limit. The upper limit, or desirable, value in the range has been established as equal to the upper level for new-construction criteria. This still provides a desirable objective for the design of the cross-section elements.

2. Lower Limit. The lower limit, or minimum, value in the range has been established by considering the minimum acceptable width for the element from an operational and safety perspective. Consider what will be available for a practical improvement by also considering that it is better to improve a greater length of roadway to a lower level than to improve a shorter length of roadway to a higher level. All of these considerations are consistent with the overall objectives of the Department's 3R program.

The width or steepness of the existing cross section should be evaluated against the criteria shown in the appropriate 55-3 series figure. If the existing width or steepness does not satisfy the minimum 3R criteria, the designer should consider widening or flattening the element. If the decision is made to widen or flatten the cross-section element, the designer should provide a design which at least satisfies the minimum 3R criteria. This will ordinarily be sufficient. However, if practical, it may be appropriate to widen or flatten the highway elements to satisfy the desirable 3R criteria.

The following summarizes the Department's 3R criteria for cross-section elements.

55-4.05(01) Travel-Lane Width

A 3R project should include practical improvements to the existing lane widths, if needed. The designer should consider the following regarding trucks.

1. Rural Arterial. Each rural arterial is on the National Truck Network and should have 12-ft travel lanes. Section 40-1.05 provides additional information on the National Truck Network.

2. Urban Arterial. For each urban arterial on the National Truck Network, the right lane in each direction should be 12 ft. For an arterial of four or more lanes, the centerline of roadway should not be shifted to accommodate the 12-ft right lane. The additional pavement width should be obtained by widening on the outside only.

3. Other Route. For another type of route, a minimum of width of 11 ft should be provided, if there are more than 200 trucks per day in the design year.

55-4.05(02) Shoulder Width

A 3R project should include widening of the existing shoulders, if needed.

55-4.05(03) Paved-Roadway Width

The paved-roadway width should not be less than that of the existing facility.

55-4.05(04) Lane and Shoulder Cross Slopes

Shoulder cross slopes on a horizontal curve should be in accordance with Section 43-3.06. The low-side shoulder should desirably be sloped as described in Section 43-3.06(02). At a minimum, the same cross slope on the shoulder should be kept in a tangent section.

Restoring or improving the pavement cross slope is often cost effective, resulting in improved ride, safety, and drainage, and maintenance of roadway pavements.

55-4.05(05) Parking Lanes

For an urban-area project, the designer must evaluate the demand for, or the elimination of, on-street parking. Section 45-1.04 provides the Department's policy for the removal or addition of on-street parking.

55-4.05(06) Curbs

The following will apply to the installation or retention of curbs.

1. Types. Where the work will disturb an existing curb, the curb is replaced in-kind.

2. Height. Pavement work may be included which does not affect the lateral location of existing curbs but will affect their finished height. The curb height, or the pavement section, should be considered for adjustment as follows:

   a. an analysis of the stormwater flow in the gutter indicates overtopping the curb for the design parameters (e.g., design-year frequency, ponding on roadway);

   b. the existing curb is deteriorated; or

   c. the curb height after construction will be less than 3 in.

3. Safety Considerations. On a facility with design speed of 50 mph or higher, existing curbs should be removed for safety considerations, if they are not needed for drainage.

55-4.05(07) Sidewalks

Where the work will disturb an existing sidewalk, the sidewalk is reconstructed or replaced in-kind, including curb ramps. Where a sidewalk does not currently exist, the need for a sidewalk will be determined as discussed in Section 45-1.06. Sidewalk construction and maintenance funding are dependent upon the project location. The following will apply.

1. Town or Rural Area. A new sidewalk constructed outside the town limits may be funded with State and Federal funds.

2. City Limit. For a sidewalk constructed within the corporate city limits with Federal funds, INDOT may elect to participate in the cost of constructing the sidewalk. For a non-Federally funded project, the city will be responsible for the costs of constructing the sidewalk. A reimbursement agreement will be required between the Department and the city prior to the

project letting. The State will be responsible for the cost of right-of-way and grading required specifically for the sidewalk.

3. Bridge. Regardless of location, the total cost for sidewalks on a bridge may be funded with State and Federal funds.

Curb ramps should be provided at all pedestrian crosswalks within the project limits. See Section 51-1.0 and the INDOT *Standard Drawings* for additional information on handicapped-accessibility requirements.

55-4.05(08) Median Width

The following will apply to median width.

1. Existing Median. An existing divided non-freeway may be improved as a 3R project. If so, the existing median width will be retained.

2. Flush Median. If the median width is 16 ft or less, the designer should consider using a continuous raised corrugated median. The INDOT *Standard Drawings* provide additional details for a corrugated median. For additional information on a flush median, see Section 45-2.02.

3. Raised Median. For additional information, see Section 45-2.02.

55-4.05(09) Fill or Cut Slopes

The following will apply to fill or cut slopes.

1. No Roadway Widening. Existing fill or cut slopes of 2:1 or flatter will be retained.

2. Roadway Widening. If the lanes or shoulders are widened, this will produce a steeper fill slope or ditch foreslope, assuming the toe of fill slope or toe of backslope remains in the same location. The roadside design should desirably be modified to provide a configuration which is the same as or flatter than the roadside cross section before the 3R project limits. At a minimum, the following will apply:

    a. Embankment slope. The use of a 3:1 slope should be considered. However, an effort should be made to construct up to a 6:1 slope at least within the obstruction-free zone where a 6:1 or flatter slope already exists, or where the length of the improvement is greater than 0.5 mi. See Section 55-5.0 for obstruction-free zone dimensions. If a steeper slope is required, a 2.5:1 slope should be considered before implementing a 2:1 slope. The slope behind the guardrail at a bridge corner should not be routinely steepened to 2:1 even though the slope may be completely protected by the guardrail. Locations or situations that may warrant a 2:1 slope are as follows:

(1) roadway widening that encroaches into a wetland;

(2) an area with restrictive or very costly right of way; or

(3) a slope at the end of a large culvert, bridge spillslope, or other location where it is desirable to protect the slope with riprap.

Where a 2:1 slope is specified, it should be protected with erosion control blankets. Capping soils suitable for growing vegetation should be provided.

The use of a 2:1 slope in a local-agency project will be at the discretion of the local agency.

Each location must be analyzed individually, and judgment should be used in selecting the slope rate.

b. Ditch. If right of way is available, the existing ditch line should be moved and the slopes flattened as much as practical. A drainage ditch in the obstruction-free zone should be regraded as much as practical to make it traversable for an errant vehicle. See Section 49-3.02 for information on traversable ditch.

c. Guardrail. Consideration should be given to obtaining a 3:1 slope in a fill to minimize the need for guardrail. An embankment should desirably be widened where guardrail will be installed as required by Section 55-5.0.

d. Embankment Stability. Sod or other stabilizing materials or methods should be provided wherever erosion may be considered to be a problem.

3. Roadside Safety. Upgrading the roadside safety is often a major objective. The designer should consider the safety benefits of flattening each fill or cut slope to eliminate guardrail and, at a minimum, to satisfy the criteria described in Item 2 above. An evaluation of run-off-the-road accidents will assist in the assessment (see Chapter Fifty). See Section 55-5.0 for more information regarding roadside-safety criteria.

55-4.05(10) Right of Way

Only minimal right-of-way acquisition should be required (e.g., lane and shoulder widening). More-extensive right-of-way involvement may be appropriate if, for example, a horizontal curve is flattened. Where practical, additional right-of-way should be secured to allow cost-effective geometric and roadside-safety improvements.

55-4.06 Intersection At-Grade

Chapter Forty-six provides criteria for the detailed design of an intersection at-grade for new construction or reconstruction. Where practical, these criteria apply to a 3R project and should be implemented. The following indicates where modifications to the intersection design criteria may be made.

55-4.06(01) General Design Controls

The criteria provided in Section 46-1.0 for intersection alignment, profile, design vehicle selection, etc., also apply to a 3R project, except as follows:

1. Intersection Alignment. Preferably, the angle of intersection should be within 20 deg of perpendicular. An existing angle of intersection of up to 30 deg may be retained if there are no operational problems or adverse accident history.

2. Y Intersection. Each existing Y intersection should be converted to a T intersection.

3. Design-Vehicle Selection. An existing intersection should be checked to determine if the suggested design-vehicle criteria shown in Figure 46-1E can be accommodated using the criteria shown in Section 55-4.06(02) for turning radius. An intersection which cannot accommodate the minimum design vehicle should be considered for reconstruction.

55-4.06(02) Turning Radius

Unless alerted by district personnel or where there is physical evidence of problems at an intersection such as tire tracks over curbs, broken curbs, or scraped utility poles, it should not be necessary to reconstruct the intersection to improve the turning radii design as part of the 3R project. However, once it has been determined to upgrade the intersection, the design should desirably be in accordance with Section 46-2.0. In an urban area, however, space limitations and existing curb radii have a significant impact on selecting a practical design for a right-turning vehicle. The designer should consider the following when determining the appropriate right-turn treatment for an urban intersection.

1. Inside Clearance. The minimum inside clearance of the selected design vehicle may be zero; i.e., the inside tire track may touch the curb line or pavement edge.

2. Encroachment. Once the decision has been made to improve an intersection, the selected design vehicle's path should be in accordance with the encroachment criteria discussed in Section 46-2.0. Under restricted conditions, an additional 1-ft encroachment is permitted for each functional classification.

3. Sweep-Path. The designer should review the existing or redesigned intersection with the turning templates to ensure that there are no obstacles in the sweep-path of the turning design vehicle.

4. Minor Intersection. At an intersection with at least one leg considered a minor road, a school bus, garbage truck, or fire truck should physically be able to make the turn onto the minor road.

The requirements regarding acceptable existing turning radius are as follows.

1. Passenger Car. A radius of 15 to 25 ft is adequate. This may be retained on an existing cross street as follows:

   a. intersection with a minor road where few trucks will be turning;

   b. intersection where the encroachment of a single-unit truck or a tractor-and-semitrailer combination onto adjacent lanes is tolerable; or

   c. intersection where a parking lane is present, it is restricted for a sufficient distance from the intersection, and it is used as a parking lane for a specified period each day.

2. Single-Unit Truck. An existing radius of at least 30 ft or a radius with taper offsets for this vehicle may be retained.

3. Tractor-and-Semitrailer Combination or Bus. At an intersection where these vehicles turn frequently, an existing radius of at least 40 ft or a radius with taper offsets may be retained.

55-4.06(03) Turn Lane

Section 46-4.0 provides warrants for a right- or left-turn lane and design requirements for an auxiliary turn lane. These should be satisfied if practical. However, the criteria for new construction or reconstruction may be impractical due to restricted site conditions. Specific examples of acceptable design criteria for an auxiliary turn lane are as follows.

1. Shoulder. An existing paved shoulder of sufficient width and pavement strength may be striped to indicate a separate right-turn lane at an intersection. If so, it may be necessary to rebuild or redesign the curb return to accommodate the selected design vehicle.

2. Reduced Travel-Lane Width. In an urban area, the width of the approaching travel lane may be reduced at a signalized intersection to provide a reasonable width for a turn lane. However, travel lanes should be at least 10 ft wide at the intersection and may be warranted to be wider if truck traffic turns must be accommodated.

3. Width. This may be narrower than that for new construction or reconstruction work.

4. Length. The length should desirably include the components for taper, deceleration, and storage as described in Section 46-4.02. These criteria may be impractical, particularly the length for the vehicular-deceleration component. However, the minimum length shown in Section 46-4.02 applies.

55-4.06(04) Intersection Sight Distance

Intersection sight distance should be in accordance with Section 46-10.0. The location of the eye should be 15 ft from the edge of the travel lane with respect to a stop-controlled intersection.

55-5.0 ROADSIDE SAFETY

Many of the improvements will have a positive effect on highway safety. In addition, a 3R project affords an opportunity to further enhance highway safety by accomplishing needed safety improvements at high-hazard locations and cost-effective adjustments or modifications to high-hazard features. Section 49-10.0 provides information on how to use ROADSIDE, a computer program which may be used to determine if roadside-safety improvements are cost effective. The following discussion offers roadside-safety criteria which apply specifically to a 3R project.

55-5.01 Analysis of Accident Data

The designer should obtain the accident history for the three-year period immediately prior to the year in which project design is initiated. The data may be summarized on the form included in Section 55-8.0 or in another convenient format.

The data should be analyzed to determine if there are any correctable accident patterns at a particular spot location of 1000 ft minimum length, intersection, or section of the highway. If a pattern exists, probable causes should be identified and appropriate safety enhancements included in the work. Each intersection or highway section which has an average of four or more accidents per year for the three-year period should be analyzed in accordance with the guidelines described in Section 55-8.0. This will require obtaining copies of the accident reports for these locations and possibly the preparation of collision diagrams. A short discussion of the probable causes and corrective action to be incorporated into the project for each intersection or highway section should be included in the Engineer's Report for an INDOT project, or in the Safety and Design Report for a local public agency project. An intersection or highway section may be experiencing the types of accidents that are correctable by highway improvements. The analysis may reveal that there is no apparent safety enhancement that can be included in the project. If this situation exists, a short discussion should be included in the Report to document that each such intersection or highway section was reviewed.

A list of high-accident locations has been developed by the INDOT Safety Improvement Program. This list is available from the Planning Division. Each 3R project should be coordinated with proposed safety projects, since the implementation of projects in one area may influence priorities in another. A safety project and a 3R project should be accomplished at the same time as practical.

55-5.02 Obstruction-Free Zone

The obstruction-free zone is defined as the roadside area next to the travelway which should be free from hazards or obstructions. This is not the same as the clear zone, so these two terms are not interchangeable. Each obstacle within the obstruction-free-zone limits should be removed, made breakaway, or shielded with guardrail. The obstruction-free-zone widths shown below are minimums and should be extended where accident experience indicates that a wider zone would further enhance safety. The clear-zone width described in Section 49-2.0 should be provided, if practical. The designer should review Section 49-2.0 for additional information on clear zone. The following obstruction-free-zone requirements apply.

1. Arterial with Shoulders. Where the design speed is 50 mph or higher and the design-year AADT is greater than 1500, the minimum obstruction-free zone is 18 ft plus the usable-shoulder width from the edge of the travelway, or from the edge of the travelway to the right-of-way line, whichever is lower. Where the design speed is 45 mph or lower and the design-year AADT is 1500 or less, the minimum obstruction-free zone is 10 ft plus the usable-shoulder width from the edge of the travelway, or from the edge of the travelway to the right-of-way line, whichever is lower.

2. Collector with Shoulders. Where the design speed is 50 mph or higher and the design-year AADT is greater than 1500, the minimum obstruction-free zone is 10 ft plus the usable-shoulder width from the edge of the travelway, or from the edge of the travelway to the right-of-way line, whichever is lower. Where the design speed is 45 mph or lower, regardless of design-year AADT, or the design-year AADT is 1500 or less, regardless of design speed, the minimum obstruction-free zone is 6 ft plus the usable-

shoulder width from the edge of the travelway, or from the edge of the travelway to the right-of-way line, whichever is lower.

The following example illustrates the computation of the obstruction-free-zone width.

Given:	
Design Criterion	3R
Design Functional Classification	Collector, Local-Agency Route
Rural or Urban	Rural
Design Speed	55 mph
Design-Year AADT	1200
Travel Lane Width	11 ft
Usable-Shoulder Width	6 ft
Paved-Shoulder Width	4 ft

The minimum obstruction-free-zone width required is 6 ft plus the usable-shoulder width. Therefore, the minimum obstruction-free-zone-width for this example is 12 ft from the edge of the travel lane.

3. Local Road or Street with Shoulders. The minimum obstruction-free zone is 6 ft plus the usable-shoulder width from the edge of the travelway, or from the edge of the travelway to the right-of-way line, whichever is lower.

4. Curbed Roadway. Where curbs are at least 6 in. in height and the design speed limit is 45 mph or lower, the minimum obstruction-free-zone width from the face of the curb should be 2 ft. However, where traffic-signal supports are present, the minimum obstruction-free-zone width should be 3 ft. Where curbs are less than 6 in. in height, or the design speed is 50 mph or higher regardless of curb height, the minimum obstruction-free-zone width should be as defined in Item 1, 2, or 3 above.

5. Appurtenance-Free Zone. There should be a 2-ft appurtenance-free width from the back face of curb or from the edge of the travel lane if there is no curb. Where traffic-signal supports are present, a 3-ft clearance should be provided. The appurtenance-free zone is defined as a space in which nothing, including breakaway safety appurtenances, should protrude above the paved or earth surface (see Figure 55-5A, Appurtenance-Free Zone). The objective is to provide a clear area adjacent to the roadway in which nothing will interfere with extended side-mirrors on trucks, the opening of vehicular doors, etc.

6. On-Street Parking.

   a. Continuous 24-Hour Parking. No obstruction-free zone is required where there is continuous 24-h parking. However, the appurtenance-free zone shown in Figure 55-

5A should be provided from the back face of the curb or the edge of the parking lane if there is no curb.

b. Parking Lane Used as a Travel Lane. The obstruction-free zone should be determined assuming the edge of the parking lane as the right edge of the farthest-right travel lane.

55-5.03 Treatment of Obstruction

An obstruction or non-traversable hazard within the obstruction-free zone should be, in order of preference, as follows:

1. removed or redesigned so that it can be safely traversed;

2. relocated outside of the obstruction-free zone to a point where it is less likely to be hit;

3. made breakaway to reduce impact severity;

4. shielded with a traffic barrier or impact attenuator; or

5. delineated if the above treatments are not practical.

55-5.03(01) Application

The following hazards should be eliminated or modified, according to the treatment hierarchy described above, if they are within the obstruction-free zone:

1. Tree. A tree maturing to a diameter of 4 in. or greater should be removed from the obstruction-free zone, unless shielded by a protective device required for other purposes. A tree on a backslope may remain if it is unlikely to be impacted by an errant vehicle.

2. Obstruction. An obstruction such as a rough rock cut, boulder, headwall, foundation, etc., with projections that extend more than 4 in. above the ground line should be removed, relocated, made breakaway, or shielded with guardrail as appropriate. A rough rock cut is one that presents a potential vehicular snagging problem.

3. Sign or Light Support. Each signpost or light pole to remain within the obstruction-free zone should be made breakaway. In an urban area where pedestrian traffic is prevalent, a breakaway light support should not be used. However, such a support should, as a minimum, be offset beyond the obstruction-free-zone width as described in Section 55-

5.02, desirably behind the sidewalk. In a rural area where pedestrian traffic is prevalent, the use of a breakaway support will be considered by the field-review team. Section 49-3.06 provides additional information on the treatment of a sign or light support within the obstruction-free zone.

4. Traffic Signal. A traffic-signal support should be placed to provide the obstruction-free zone through the area where the traffic-signal supports are located. However, the following exceptions will apply.

    a. Channelized Island. Installation of a signal support in a channelizing island should be avoided, if practical. However, if a signal support must be located in a channelizing island, a minimum clearance of 30 ft should be provided in a rural area from all travel lanes, including turn lanes, or in an urban where the design speed is 50 mph or higher. In an urban area where the island is bordered by a vertical curb and the design speed is 45 mph or lower, a minimum clearance of 10 ft should be provided from all travel lanes, including turn lanes.

    b. Non-Curbed Facility, Design Speed $\geq$ 50 mph or AADT $>$ 1500. Where conflicts exist such that the placement of traffic-signal supports outside the obstruction-free zone is impractical (e.g., conflicts with buried or utility cables), the signal supports should be located at least 10 ft beyond the outside edge of the shoulder.

    c. Non-Curbed Facility, Design Speed $\leq$ 45 mph or AADT $\leq$ 1500). Where conflicts exist such that the placement of traffic-signal supports outside the obstruction-free zone is impractical (e.g., conflicts with buried or utility cables), the signal supports should be located at least 6 ft beyond the outside edge of the shoulder.

5. Culvert. A culvert end is considered to be within the obstruction-free zone if the point at which the top of the culvert protrudes from the slope is within the obstruction-free zone. Section 55-5.03(02) provides additional information for the treatment of a drainage structure.

6. Transverse Slopes of Public Road Approach or Drive. Steep transverse slopes should be considered for flattening, if practical. Such slopes should desirably be 6:1 or flatter, not steeper than 4:1. Transverse slopes on a median crossover should be 10:1 or flatter.

7. Curbs. Curbs should be removed from a rural highway where the design speed is 50 mph or higher. The proper placement of traffic control devices must be considered in reviewing the removal of corner island curbs where such devices are located. This is not intended to address divisional, or channelizing, islands separating two-way traffic or a curb placed at the edge of a shoulder for drainage. For these situations, sloping curbs should be used.

    Curbs of at least 4 in. in height should not be used in conjunction with guardrail. The front face of a curb used in conjunction with guardrail should desirably be behind the face of the rail. If this cannot be achieved, the front face of the curb may be located flush with the face of the rail.

8 Utility Pole. A utility pole within the obstruction-free zone which is not owned by INDOT or a local agency can constitute a significant hazard and should be removed or relocated. The utility company should be requested to relocate poles that are located in a high-vulnerability area such as a channelizing island, or where the accident history indicates there has been a utility-pole-accident problem. The field-review team, based on its judgment, will determine where such work is warranted.

9. Mailbox Support. Each new mailbox installation should be placed in accordance with the INDOT *Standard Drawings*, INDOT *Standard Specifications*, and Section 51-11.0.

10. Non-Traversable Hazard. A fill slopes steeper than 1:1 with a height greater than 2 ft within the obstruction-free zone should be flattened to the extent practical. If part of a drainage ditch appears within the obstruction-free zone, its cross section should be in accordance with the criteria described in Section 49-3.02.

11. Drainage Ditch. A ditch is considered inside the obstruction-free zone if the near side of the ditch bottom is within the obstruction-free zone.

If a ditch is located inside the obstruction-free zone, the ditch should be traversable. See Section 49-3.02. If the ditch it is not traversable, a Level Two design exception is required. If a traversable ditch is not provided, a 4-ft wide bottom should be provided for the ditch with the backslope as flat as practicable.

If a ditch is located outside the obstruction-free zone, design exception is not required regardless of which of the following alternates, ranked in order of preference from top to bottom, is used.

a. The ditch should be made traversable. Although it is not mandatory to provide a traversable ditch section, this can be accomplished but should only be pursued where the gentler section does not significantly affect the right-of-way needs.

b. A 4-ft flat-bottom ditch should be provided.

c. A flat-bottom ditch of less than 4-ft width should be provided.

d. A V ditch should be provided.

With respect to Items b, c, and d, the backslope should be designed to be as flat as practicable.

12. Other Hazard. The designer should review Section 49-3.0 to determine the appropriate treatment for other hazards not discussed above, such as a bridge pier or bridge-railing end.

55-5.03(02) Drainage Structure

A mainline cross culvert of 60 in. diameter or less, or a pipe-arch 84 in. x 60 in. or smaller, should not be extended to locate the inlet and outlet ends outside the obstruction-free zone. This practice can introduce undesirable embankment slope discontinuities. A structure which is terminated within the obstruction free zone should be treated as follows:

1. Standard metal culvert-end sections should be used within the obstruction-free zone with a circular culvert of at least 30 in. diameter, or with a pipe-arch culvert of at least 36 in. x 24 in., either of which is skewed 10 deg or less from the perpendicular, towards the direction of approaching traffic.

2. Grated-box end sections should be used with a circular culvert of diameter of 30 in. through 60 in., or with a pipe-arch culvert of 45 in. x 27 in. through 84 in. x 60 in.

3. Grated-box end sections should be used with a culvert which is skewed more than 10 deg from the perpendicular, towards the direction of approaching traffic.

4. If the end of a culvert of 66 in. diameter or larger is within the obstruction-free zone, guardrail should be provided. If the culvert end is outside the obstruction-free zone, the designer should use engineering judgment to determine if it is desirable to protect an errant motorist from the culvert end with guardrail. If there is inadequate height of cover to drive the guardrail posts, the treatment shown for guardrail over a low-fill culvert in Section 49-5.03 and the INDOT *Standard Drawings* should be used.

5. If the point at which the top of a box culvert or three-sided structure protrudes from the slope is within the obstruction-free zone, guardrail should be provided. Otherwise, Figure 55-5A(1), Clear Zone / Guardrail at Culvert, should be used to determine the appropriate treatment.

Each culvert of 36 in. or 42 in. diameter that is parallel to the mainline and inside the obstruction-free zone, or is within a median of 60 ft width or less, requires standard metal or concrete end sections. Each culvert of greater than 42 in. diameter that is parallel to the mainline and inside the obstruction-free zone, or is within a median of 60 ft width or less, requires grated-box end sections.

55-5.04 Roadside Barrier

Each existing safety appurtenance should be examined to determine if it is in accordance with the current safety performance and design criteria. This includes guardrail, median barrier, impact attenuator, sign support, luminaire support, or bridge railing. Substandard safety appurtenances should be upgraded to be in accordance with the current safety performance and design criteria. Chapter Forty-nine and the INDOT *Standard Drawings* provide the Department's criteria for the layout and design of safety appurtenances.

55-5.04(01) Existing Guardrail

An existing guardrail installation should be removed where such installation is not in accordance with the location warrants described in Section 49-4.0 or where the obstacle or hazard can be removed at a cost of less than guardrail upgrading plus estimated guardrail maintenance costs over the life of the installation. If existing guardrail is still warranted, it should be upgraded as follows:

1. Guardrail Components. Each guardrail and end treatment which is not in accordance with Section 49-4.0 and the INDOT *Standard Drawings* should be replaced or upgraded to the current criteria. However, existing W-beam guardrail with U-channel rubrail may be retained. An existing buried-end section may remain on a two-lane local-agency route if the design-year AADT is less than 1000.

2. Transition. Each substandard guardrail transition to a bridge pier or other obstruction should be upgraded or replaced to be in accordance with Section 49-4.0 and the INDOT *Standard Drawings*.

3. Height. Guardrail of less than 2'-3" height at the top of the rail element should be raised using adjustable blockouts, or reset or replaced as appropriate.

4. Lateral Clearance. Reduced post spacing should be provided where the distance between guardrail and an obstruction is less than the required deflection distance shown in Section 49-5.0.

5. Gap. Each gap of 200 ft or less between guardrail runs should be closed, if practical.

6. Length of Need. Each guardrail run's length of need should be in accordance with Section 49-5.0. The obstruction-free-zone width shown in Section 55-5.02 should not be used as the clear-zone width in determining the length-of-need requirement. The clear-zone width for computing the length of need is shown in Section 49-2.01. The length of need may be modified if deemed appropriate by the field-review team. See Figure 55-5B, Runout Length, L_R, (ft) for Restrictive Condition.

55-5.04(02) New Guardrail Installation

New guardrail should be installed as follows:

1. where it is not practical to eliminate an obstacle from the obstruction-free zone as defined in Section 55-5.03;
2. where the guardrail is judged to be less hazardous than the obstacle;
3. at each approach to a bridge railing; and
4. where in the opinion of the field-review team, there is an extreme hazard which obviously warrants guardrail.

Each new installation of guardrail should be in accordance with Chapter Forty-nine and the INDOT *Standard Drawings*, except as follows.

1. Length of Need. The length of need may be modified by the field-review team if deemed absolutely necessary.

   Guardrail Offset. The desirable guardrail offset is 2 ft from the effective usable-shoulder width, or the shy-line offset distance, whichever is larger. See Figure 49-5F for shy-line offsets. The minimum guardrail offset distance is 4 ft from the edge of travelway. In a restrictive situation, depending on functional classification, this distance may be 0 ft.

2. Post Embedment and Earth Backup. The desirable distance from the face of guardrail to the shoulder break point is 3 ft. In a restrictive situation, this distance may be 0 ft.

3. End Treatment. The type I end treatment may not be used on an INDOT route, or other facility which has a design year-traffic volume of 1000 AADT or greater. Section 49-5.04 provides additional information on end treatments which may be used on a high-volume, high-speed road.

5. Length of Need for Restrictive Condition. Where a restrictive condition warrants, Figure 55-5B, Runout Length, L_R (ft), for Restrictive Condition, should be used

One example of a restrictive condition is the close proximity of a drive to the end of a bridge, which cannot be relocated farther from the bridge.

If it is decided at the field check to shorten a guardrail run's length of need, the field check minutes must document the decision.

55-6.0 BRIDGE

55-6.01 General Requirements

An existing bridge may remain in place if it satisfies, or is upgraded to satisfy, the structural and geometric requirements shown in the appropriate figure in the 55-3 series, and in Section 55-6.02. Upgrading a bridge to satisfy the criteria should only be undertaken if an engineering and economic analysis shows that the upgrading is cost effective. Some of the considerations for such an analysis include the following:

1. remaining service life;
2. sufficiency rating;
3. traffic volume;
4. clear-roadway width;
5. snow storage;
6. farm equipment clearances;
7. design speed; and
8. accident records.

If it is decided that a bridge should be replaced or have major reconstruction (e.g., replace superstructure, widen superstructure, or widen substructure), the design should be done in accordance with the appropriate AASHTO criteria and load-carrying capacity (see Chapter Sixty). The only exception is that the bridge-width criteria shown in Section 55-6.03 may be used if the most likely level of future (20 to 30 years) highway improvement on the approaches and adjacent road sections will be to 3R criteria (i.e., the road will not be reconstructed in the foreseeable future). Reasons for determining the use of the width shown in Section 55-6.03 must be documented in the Preliminary Engineering Study for an INDOT-route project, or in the Safety and Design Report for a local-agency-route project. The width shown in Section 55-6.03 may also be used for a bridge which is part of a 3R project, an isolated bridge on existing alignment, or an isolated bridge where the alignment has been changed. In the latter situation, the minor-roadway realignment may be constructed to 3R criteria as described in this Chapter.

55-6.02 Bridge To Remain In Place

If an existing bridge is structurally sound and if is in accordance with the appropriate AASHTO design loading for structural capacity, it is unlikely to be economical to improve the geometrics of the bridge. If an existing bridge is not in accordance with the following, it should be evaluated for upgrading or replacing (see Section 55-6.01). The following will apply to an existing bridge.

1. Width. The width should be evaluated against the criteria shown in the appropriate figure in the 55-3 series.

2. Structural Capacity. The structural capacity should be evaluated against the criteria shown in the appropriate figure in the 55-3 series.

3. Vertical Clearance. An existing structure should provide at least a 14.0-ft vertical clearance. If this vertical clearance is not available, consideration should be given to increasing the vertical clearance either as part of the 3R project or as a separate project. Modifications should desirably provide for a clearance of 14.5 ft. If it is necessary to retain a vertical clearance of less than 14.0 ft, a design exception request must be processed in accordance with Section 40-8.0. Low-clearance signage is required for a vertical clearance of less than 14.5 ft.

4. Bridge Railing. Only existing bridge railing that has been proven to be acceptable through crash testing or that satisfies the structural and geometric requirements of the AASHTO *LRFD Bridge Design Specifications* may be retained. Each new bridge-railing installation must be in accordance with Section 61-6.01. Consideration should be given to widening the bridge at the same time the railing is replaced to achieve the full approach travelway and shoulder width.

   A design exception to this criterion will only be considered if all of the conditions are satisfied as follows:

   a. the project is a rehabilitation project on a non-NHS route;

   b. the existing bridge railing and approach guardrail are considered to be satisfactory;

   c. the accident history does not indicate that there may be a problem;

   d. the design year AADT is less than 400; and

   e. the design speed is 30 mph or lower.

5. Narrow Bridge. Each bridge which is narrower than the approach roadway width, and is not to be widened, should be signed and pavement-marked as shown on the INDOT *Standard Drawings*. NCHRP 203 *Safety at Narrow Bridge Sites* provides criteria specifically for a narrow bridge, e.g., pavement markings.

55-6.03 Bridge Requiring Replacement or Major Reconstruction

The new-bridge clear-roadway width shown in the appropriate figure in the 55-3 series is intended to be applied only to a bridge where it has been determined that the 3R criteria is the most probable level of future (20 to 30 years) highway improvement on the approaches and adjacent roadway sections. If the expected improvement will be reconstruction, the width shown in the appropriate figure in the 55-3 series should be used. The 3R bridge work may include rehabilitation using structurally-sound elements of an existing bridge, complete bridge replacement on existing alignment, or a replacement bridge on a short relocation. This width is a minimum, and a greater width should be used if deemed appropriate.

The minimum clear-roadway width is the sum of the lane widths and shoulder widths (or curb-offset widths) shown in the appropriate figure in the 55-3 series, plus the offset distance for guardrail. The intent is to carry the 3R roadway cross section across the bridge. The minimum clear-roadway width should be 30 ft on a rural INDOT route.

Future bridge-deck rehabilitation work may necessitate a greater minimum clear-roadway width than indicated above. The width must be at least 30 ft if bridge-deck rehabilitation is to be done on one-half the width at a time. However, on a local road or street, this 30-ft minimum width may not be necessary if it is determined that it is practical to close the bridge and detour traffic once such work becomes necessary.

The use of the road by agricultural equipment may also necessitate the use of a clear-roadway width greater than the minimum prescribed herein. The need for a greater width to accommodate such equipment will be determined for each project. Approach guardrail should be offset to the same position as the bridge railing from the edge of the traveled way, if a clear-roadway width greater than that of the approach roadway (traveled way plus shoulders) is used.

Each bridge must be designed to comply with the AASHTO load-carrying capacity requirement shown in the appropriate figure in the 55-3 series. Each new bridge-railing installation must be in accordance with Section 61-6.01. The waterway opening will be determined in accordance with the applicable environmental-permit requirements.

55-7.0 MISCELLANEOUS DESIGN ELEMENTS

55-7.01 Traffic-Control Devices

All signs, traffic signals, and pavement markings on the mainline and intersections, and related traffic-control devices on public road approaches must be in accordance with Part VII and the *MUTCD*. Center-line and edge-line pavement markings, no-passing zone warning signs, and regulatory signs are required. It may be necessary to extend pavement markings and place related signs beyond the project limits to end them at a logical terminus (e.g., major intersection, end of a no-passing zone). Center lines and edge lines need not be installed where they are not warranted, based on the opinion of the field-review team. For example, pavement markings would not be warranted on a bridge-replacement project on a road that does not have pavement markings.

55-7.02 Railroad Crossing Warning Devices and Surface

The adequacy of existing warning devices and crossing surface should be investigated if the 3R project includes an at-grade railroad crossing within the project limits. A railroad grade-crossing surface should provide for a reasonably smooth ride and should have a width equal to at least the approach traveled way plus shoulders plus 1 ft on each side. A railroad crossing which does not satisfy the above surface requirements should be upgraded concurrent with the 3R work. If an active warning-device installation or upgrading is determined to be necessary, it should also be done concurrent with the 3R project. For more information on upgrading an at-grade railroad crossing, see Chapters Eleven and Forty-seven.

55-7.03 Trimming of Trees and Brush

Trees and brush should be trimmed, as necessary, to obtain the required stopping, intersection, or railroad-crossing sight distance and signage visibility.

55-7.04 Encroachment

Each encroachment within the right of way should be treated in accordance with Section 86-2.0.

55-8.0 ACCIDENT DATA ANALYSIS

A primary measure of the safety of an existing highway is its accident history. Once a highway location has been proposed, accident data should be collected and analyzed to determine the relative safety of the facility and to identify and describe the accident characteristics or patterns that have occurred. Safety enhancements to alleviate safety deficiencies can be more-readily identified from this analysis, and the extent of minimum safety enhancement can be determined.

55-8.01 Accident-Analysis Procedures

55-8.01(01) Responsibilities

In conducting an accident analysis, the duties to be performed are as follows:

1. be prepared to spend sufficient time conducting the accident study;

2. study individual accident reports;

3. check project termini, often at some logical point such as an intersection, to ensure that accident information is considered just beyond the project termini;

4. relate accident data to field conditions, preferably if there are only a limited number of accidents reported. Review the data in the field or on the videolog; and

5. discuss the project with maintenance personnel. Many single-vehicle or non-injurious accidents are unreported and yet are strong indicators of potentially hazardous situations.

55-8.01(02) Accident Summaries

Accident analysis study procedures involve determining the significance of the accident history and the development of summaries of the accident characteristics within the 3R project termini. The project's accident summaries are used to detect abnormal accident trends or patterns and to distinguish between correctable and non-correctable accident experience. Analysis of these summaries is needed to identify probable safety deficiencies of the existing facility.

In conducting the accident analysis, the following should be considered.

1. Time Period. The required time period for the collection of the accident history is three years. In selecting the period, the accident data should represent reasonably current information, as related factors such as traffic volume, pavement condition, or other site-related data can vary with time. Likewise, the past changes in the character of the facility (e.g., physical changes, roadside development) should be accounted for when evaluating the accident activity.

2. Vehicle Directions. The accident data should be examined to determine the directions the vehicles were traveling.

3. Location. Accident data should be examined with respect to location. Accidents occurring within an intersection area should be separated from those occurring outside the area of influence of the intersection. Similar accident types occurring in differing situations should be separated. For example, left-turn accidents into a drive should not be included with left-turn accidents at an intersection.

4. Accident Rate. The accident data should be examined to determine the number of accidents and the accident rates within the project termini. Limited accident data is likely on a rural 2-lane highway with a low to moderate traffic volume. The limited amount of such data can make traditional methods of analysis difficult. Accident rates generated from a small sample can be misleading as they can be significantly influenced by small variances.

5. Summary Form. The accident data should be summarized by type and severity. Figure 55-8A, Accident Analysis Form, provides a typical accident summary form that may be used to analyze accidents. An editable version of this form may also be found on the Department's website at www.in.gov/dot/div/contracts/design/dmforms/. Figure 55- 8B, Accident Analysis Form Codes, and Figure 55-8C, Collision Diagram Codes, provide the codes which are used in conjunction with Figure 55-8A.

6. Accident Analysis. Once the accident data has been compiled, the data should be reviewed to identify accident patterns and determine possible causes for the accident patterns. The severity patterns should be examined to determine if a particular roadway or roadside feature may have contributed to the overall severity of the accidents that have occurred. Section 55-8.02 provides additional information on probable accident causes and possible safety enhancements.

7. Contributing Factors. The Contributing Circumstances portion of the accident report should be summarized. This identifies possible accident causes noted by the investigating police officer at the scene of the accident. Contributing circumstances are categorized by human (driver), environmental, or vehicle-related factors. The contributing-circumstances information is used to verify, add, or delete possible causes developed by the accident-summary-by-type procedure. The contributing-circumstances information can be used to separate correctable and non-correctable accidents. In separating the accidents by these classifications, consideration should be made to ensure that the accidents are indeed non-correctable. Figure 55-8D lists the contributing circumstances found on most accident reports, and if they are correctable or non-correctable through highway improvements.

8. Environmental Factors. Accidents should be summarized by environmental conditions. This procedure identifies possible causes of safety deficiencies related to the existing condition of the roadway environment at the time of the accident. Typical classifications used in the analysis include lighting conditions and roadway surface condition. The summary is compared to average or expected values for similar locations or areas to determine whether the occurrence of a specific environmental characteristic is greater or less than the expected value at the location. For example, a higher-than-expected number of wet-surface accidents may be an indication of slippery pavement.

55-8.02 Probable Causes and Safety Enhancements

Probable accident causes should be defined once the accident patterns are identified. Field conditions, as determined by an on-site or videolog review, or from information on the police accident report or computerized accident form, should be used to refine the list of possible causes to the most probable. The identified probable causes can then be used as a basis for selecting appropriate safety enhancements to alleviate the safety deficiency. Figure 55-8E, Accident Analysis, provides a list of probable accident causes and possible safety enhancements. This list is not all-inclusive. However, it does provide a general list of possible accident causes as a function of accident patterns and appropriate safety enhancements.