Committee Research Problem Statements
Design and Construction Group (AF000)
Design Section (AFB00)
Geometric Design Committee (AFB10)

Preface

An important function of the Transportation Research Board (TRB) is to stimulate research that addresses problems facing the transportation community. In support of this function, TRB technical committees identify problems, and develop and disseminate research problem statements for use by practitioners, researchers, and others. The problem statements listed below were developed by the TRB committee noted above. These problem statements should not be considered comprehensive; they may only represent a portion of overall research problems identified by committee members.

Problem Number	Priority	Problem Statements	Date Posted
1	1	Safety, operations, and usability trade-offs between user groups	08/05
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4	4	Operational and Safety Impacts of Angle versus Parallel versus Back-in Parking	08/05
5	5	Accommodating Bicycles on Rural Highways	08/05
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9	9	Design, Safety and Operations of Pedestrian Geometric Intersection Treatments	08/05
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11	11	Operational and Safety Impacts of Four- and Six-Lane Sections with Raised Medians versus Two-Way Left Turn Lanes	08/05
12	12	Intersection design to accommodate pedestrian crosswalk cross slope	08/05
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15	15	Right-Turn Interactions and Channelized Right-Turns	08/05

I. Problem Number 1: Safety, operations, and usability trade-offs between user groups

II. Research Problem Statement

Current geometric design guidelines for highways and streets do not adequately anticipate or accommodate the needs of all potential users. Pedestrians and bicycles are common users of the urban and rural transportation network, especially at intersections. Designs that accommodate their needs are often viewed as retrofit or add-ons rather then as being given equal importance. There are several issues related to safety of the users and the identification of the unique problems that these users experience is of utmost importance. Therefore, having an understanding of the problems and issues for these users, solutions could be sought to reduce, if not eliminate, potential problems. A possible approach for addressing this issue is the trade off between design elements for vehicles and other users. However, there is little knowledge as to the safety consequences form such design element trade offs.

III. Literature Search Summary

There is limited research in this subject area. Several studies have been conducted that dealt with the safety of the various non-vehicle roadway users but little has been done to correlate the design element trade offs that can be implemented to improve the safety and operational level for the non-vehicle roadway users. There has been limited work that could form the basis for this work and include:

- NCHRP Project 15-20 “Planning, Design, and Operation of Pedestrian Facilities.” The objectives of this recently completed research were to develop a guide for planning and designing pedestrian facilities. The findings of the study are to be considered for incorporation in the next edition of the Green Book.
- AASHTO design guides (A Policy on Geometric Design for Highways and Streets; Guide for Developing Bicycle Facilities; and Guide for the Planning, Design and Operation of Pedestrian Facilities)
- ADA Requirements and guidance

IV. Research Objective

The objective of this research is to develop guidelines for addressing the needs of roadway users especially at intersections. The work to be completed should address the trade offs between design elements and safety and operational performance of these facilities.

The research should include a literature review of previous research and current practice in regard to pedestrian and bicycle facilities design, development of a work plan to achieve the research objectives, collection of applicable field data and other information, evaluation of the safety and operational effects of various combinations of design elements, and preparation of a final report. The final report should include proposed changes to AASHTO Policy, if results support a change.

V. Estimate of Problem Funding and Research Period

Recommended Funding: $500,000
Research Period: 30 months

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics at their combined meeting in June 2004 as one of the high priorities for research. The research is needed to fill performance gaps in current roadway design to address and accommodate the needs of all roadway users. It will be of use in the design of highways nationwide.

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VIII. Problem Monitor

TBD

IX. Date and Submitted by

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I. Problem Number 2: Multimodal Design to Create "Complete Streets"

II. Research Problem Statement

There is increasing recognition that successful highway designs, and particularly successful designs for urban streets, must effectively serve all transportation modes and provide an appropriate balance among those modes. An effective street design must accommodate motor vehicles of all types, pedestrians, bicycles, and transit. Facilities for each transportation mode must be provided, with the modes safety separated; space must be provided for roadside hardware and underground and above-ground utilities; and the design must fit within the context of adjacent development. Any street design that successfully meets all of these needs can be referred to as a "complete street."

While the need for "complete streets" has been recognized, and much has been written about the importance of multimodal considerations, there is little practical guidance on how to effectively serve all transportation modes along the same facility or corridor.

Most available design guidance deals with design for a particular mode, but not with how serve the competing needs of multiple modes.

Part of the challenge of creating multimodal design is to recognize that the mix of transportation modes, and the priority that should be given to each differs by functional class. Thus, there is a need to determine the primary and secondary users of each highway functional class and assess how best to serve the mix of users found on each class.

III. Literature Search Summary

A literature search has fund extensive work on multimodal planning, especially on an areawide basis, but very little on multimodal design at the level of an individual facility.

IV. Research Objective

The objective of the research is to identify the mix of users, including primary and secondary users, that needed to be served on various highway functional classes; to identify the types and designs of facilities needed to serve each of those types of users; to develop examples showing how those types of facilities have been or could be designed effectively as part of the same corridor; and to present the results in the form of multimodal design guidelines for specific highway functional classes. The first objective—identifying mixes of user on specific functional classes—should address the full range of highway functional classes. The latter objectives could also address a range of functional classes or could focus on selected functional classes of interest.

For specific functional classes, the research should develop examples of projects that have effectively implemented multimodal designs and should highlight the features of those designs that allow multiple transportation modes to be served both safely and effectively. The research should also suggest new concepts that could be considered in future projects.

The design guidance developed should be both integrated and multimodal. The guidelines should not discuss each transportation mode in separate chapters. There is plenty of separate material on each mode in other sources to make reference to. Instead, the guidelines should focus on fitting the individual modes together into an integrated facility that meets the needs of each in a balance appropriate for the functional class of the facility. The guidelines should indicate the expected operational and safety performance of alternative approaches to facility design.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$300,000
Research Period:	2 years

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics at their combined meeting in June 2004 as a priority issue from among a broader set of problems considered. The research is needed to address an unresolved issue in highway geometric design. The research results should be presented in a stand-alone document that can be used to supplement existing design policies and manuals.

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I. Problem Number 3: Safety Effects of Intersection Skew Angle

II. Research Problem Statement

Where two roads intersect, the most desirable intersection angle is 90 degrees. However, because of physical and other constraints, many roads meet at angles less than 90 degrees. Such locations are referred to a *skewed intersections*, and the difference between 90 degrees and the smallest acute angle between the intersection legs is referred to as the *intersection skew angle*.

The AASHTO *Green Book* presents a policy on design of intersections to minimize the deviation from a 90-degree intersection angle. This Green Book recommends a minimum intersection angle of 60 degrees and this guidance has been adopted in the geometric design policies of many highway agencies. However, little information about the safety effects of intersection angle is available. It is likely that current design policies on intersection skew angle are based on engineering judgment rather than the results of safety research.

III. Literature Search Summary

McCoy et al. found, in research for the Nebraska Department of Roads (Project RES1, 1994), that accidents increase with increasing skew angle at rural two-way stop controlled intersections. Hanna et al. (TRR 601, 1976) found that three-leg Y intersections had accident rates approximately 50 percent higher than there-leg T intersections, suggesting an effect of intersection skew angle. A Finnish study by

Kulmala (1995) found that acute and obtuse skew angles affected safety differently. Harwood et al. (FHWA-RD-99-207, 1999) selected an accident modification factor (AMF) for intersection skew angle, based on a negative binomial regression model, for application to STOP-controlled intersections on rural two-lane highways in FHWA's Interactive Highway Safety Design Model (IHSDM). None of these research results are considered sufficiently definitive for form a basis for reevaluation of the appropriate geometric design policy for intersection skew angle. The FHWA Older Highway Design Handbook has recommended that intersection skew angles be reduced for the benefit of older drivers, but the handbook offers no quantitative estimate of the benefit to older drivers, or to motorists in general, from doing so.

IV. Research Objective

The objective of the recommended research is to establish quantitative relationships between intersection skew angle and safety and to use those relationships to consider the need for revision of current geometric design policies concerning intersection skew angle.

The scope of the research should include both a range of intersection types including rural and urban locations, three- and four-leg intersections, and STOP- and signal controlled intersections. The research should consider the effect on safety of the magnitude of the intersection skew angle and the orientation of the intersection leg to approaching traffic (e.g. acute vs. obtuse angle).

The research should focus on intersections with angles between 60 and 75 degrees and should assess whether an increase in the current minimum intersection angle of 60 degrees would provide safety benefits. The research should also assess the potential for increased construction costs and other impacts if the minimum intersection angle were to be increased. The assessment of the need for changes in intersection skew angle should consider both the costs and the benefits of any proposed change in design policy. If a change in design policy is recommended, draft text for revision of the AASHTO Green Book should be provided in the final report of the research.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$400,000
Research Period:	3 years

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics at their combined meeting in June 2004 as a priority issue from among a broader set of problems considered. The research is needed to address an unresolved issue in highway geometric design. The research results can be implemented through incorporation in the AASHTO *Green Book.*

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I. Problem Number 4: Operational and Safety Impacts of Angle versus Parallel versus Back-in Parking

II. Research Problem Statement

There is a sizable body of literature examining the safety effects of angle and parallel parking. What is not always evident is:

- the context within which these findings are applicable (surroundings, traffic volumes);
- the safety effects of back-in angle parking;
- the safety effects of buffer spaces between through traffic lanes and parking lanes;
- guidelines for allocating cross-section width between bicycles and parked vehicles;
- the needed cross-section width for parallel parking; and
- the economic effects of different parking choices.

There has been some recent experimentation with back-in angle parking as an alternative to head-in angle parking. Current research in Rhode Island is examining tradeoffs between bike lane width and parking width. The pavement marking diagrams in recent versions of the MUTCD have called for a marked parallel parking stall that is 8 feet wide; some recent design publications have specified less width.

With the emphasis in and growth of New Urbanism and Context Sensitive Design, traffic engineers need more definitive studies and explanations of the tradeoffs and affects of prohibiting or allowing various types of on-street parking arrangements.

III. Literature Search Summary

Curb parking was found to be directly involved in 17 to 18% of all accidents on urban streets; the rate of parking accidents per mile was eight times greater on major streets than on minor (Box 1970). Humphreys et al. (1979) reviewed data from ten cities, finding that over 50% of non-intersection crashes involved parking. McCoy et al. (1990) surveyed 135 miles of urban state highway with curb parking. Data were collected from 22,572 parallel spaces and 6,314 angle spaces in a number of cities and towns. Overall, 26% of the nonintersection accidents on major streets and 56% on two-way, two-lane streets were parking accidents. In one study, the cost of parking accidents was found to be about half of the average (Rankin).

Edwards (2002) advocated angle parking because it provides a wider "buffer" between sidewalks and driving lanes, which helps reduce vehicle splash, noise and fumes, and helps improve the perception of safety for the pedestrian. Many consider angle parking to be more dangerous than parallel (Rankin). In a synthesis of a number of studies, Box (2002) found higher accident rates for angle parking than for parallel, with a few exceptions. A Nebraska study found higher accident rates for angle parking by any measure as compared with parallel parking (McCoy et al.). Humphreys et al. (1979) concluded the crash rate increased with land use type: the lowest being associated with residential, and increasing with multifamily, office, and retail. The level of use rather than the parking configuration appeared to be the key to the midblock accident rate: for streets with over 600,000 parking space hours per kilometer per year, parallel parking is not safer than angle parking, given similar land uses. Zeigler (1971) said that parking at an extremely flat 22.5^{O} angle with the curb was proven to be quiet safe and user-friendly.

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Zeigler, C.D. (Aug. 1971) "A Study of On-Street Parking Arrangements." Research Report SS 19.1, Texas Highway Department, District Seventeen.

IV. Research Objective

The objective of this research is to more fully investigate and document the effects and tradeoffs of allowing or prohibiting on-street parking. Issues to examine include:

1. under what conditions should on-street parking be allowed or prohibited;
2. if parking is allowed, under what conditions should it parallel, head-in angle, or back-in angle;
3. how much cross-section width should be allocated for a parked vehicle or for bicycles;
4. what are the economic effects of these choices?

The project should include a literature review of previous related research.

The safety effects of on-street parking could be better examined using data from those locales that have improved their crash reporting processes by means such as using satellite crash location technology. The context of studies needs to be better defined: factors such as abutting land use type and street traffic volumes should be reported, and both data and findings should be stratified by context, so that findings taken from one environment are not applied without justification to other environments.

A necessary component to this research will be findings from agencies that have experimented with back-in angle parking, a buffer strip between travel lanes and angle parking, and the flat-angle parking advocated by Ziegler.

An examination of the effects of curb parking upon business and the community would be helpful. A confounding problem is that it is not uncommon for parking enhancements to be accompanied by other area improvements.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$275,000
Research Period:	30 months

VI. Urgency, Payoff Potential, and Implementation

Traffic engineers in urban settings are sometimes pressured to permit on-street parking, which in some situations may be unsafe. Findings from this study would help them evaluate specific situations and distinguish between those where on-street parking could be allowed and those where it should be opposed.

Additional research will be of little benefit unless an effective technology transfer method to get the information into the hands of practitioners and local political leaders is employed.

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VIII. Problem Monitor

TBD

IX. Date and Submitted by

TBD

I. Problem Number 5: Accommodating Bicycles on Rural Highways

II. Research Problem Statement

Much research has been done related to accommodation of bicycles in urban and suburban areas, but much less has been carried out that addresses bicycles on rural roads. As more rural roads are being used in various parts of the country for recreational bicycling purposes, there is some question as to when to provide special attention to bicyclists, particularly when most rural roads do not consider bicyclists in their design. Also, there is a need to better understand and communicate which design features are most appropriate in the rural environment to accommodate bicyclists.
The product of this research will be used to determine when to better accommodate bicyclists on rural roads and what design features are best to accommodate them. It will be used by state and local road officials with jurisdiction over rural roads.

III. Literature Search Summary

Searches in TRIS and Research in Progress did not reveal much information in this regard. However, a recent report entitled “Development of Rural Bicycle Compatibility Index” from Nebraska (Jones, E., July 2004) provides a fairly extensive literature review. Most of the literature cited by Jones, consistent with her research goal, indicates that much of the research concerns the compatibility of existing roads for use by bicyclists. Likewise, much of the research centers on urban and suburban roads and may or may not be true for rural roads. However, one obtains a good idea of the types of roadway characteristics that affect the ability of a bicyclist to safely and comfortably use a road.

Jones cites Shorton and Walsh who examined factors such as curb lane traffic volume, speed of vehicles, curb lane width, commercial driveways per mile along a street, and percentage of heavy vehicles as factors that may impact a bicyclist using a given roadway. Landis, et.al. looked at pavement surface conditions in a similar vein. Harkey and Stuart found that motorists are less likely to encroach on an adjacent lane when passing a bicyclist on a paved shoulder. As well, bicyclists will ride further from the edge of roadway when they are on a paved shoulder. Smith found that when heavy vehicle speeds are 60 mph or greater, a separation distance of 6 feet or more is necessary for tolerable riding conditions. In concluding her work, Jones states that highways with low truck volumes and wide shoulders to ride on will be more comfortable for most rides.

The current research will build on work performed by Jones and those cited in her work. The research will consider the compatibility of a roadway for bicycles, but package the "compatibility" of the roadway in a manner that clearly identifies when a road authority ought to improve the conditions of the road to make it more safely and comfortably useful by bicycles. In addition, the work will take the criteria used for compatibility and other information to establish a practical set of potential countermeasures that can be considered for application once a road is designated as in need of improvements for bicycles.

The Maine Department of Transportation (Smith, Balicki and Pesci) has an ongoing research project on safe ways to school. They are looking at sort term measures to encourage walking and bicycling to school in both urban and rural sites. They have also recommended a long term approach that includes engineering, education, enforcement and encouragement measures. Maine also has research in progress on gravel stabilization methods. One of the goals of the research is to examine the ability of gravel stabilization to increase bicycle access and rideability. Colorado DOT is examining advance warning (signs and pavement markings) of rumble strips for bicyclists. The ultimate goal is to develop a rumble strip warning configuration that will be used to ensure that bicyclists are not surprised by the presence of rumble strips.

The proposed research is different than the ones cited above in two ways. First, the MDOT work in the first project was entirely focused on safe ways to school whereas the current research will be more universally applicable for all bicycle users on rural roads. With regard to the second MDOT project, the work is not focused on bicycle users as is the proposed research. Specifically, in reading an abstract, it appears that bicycle safety and comfort is a potential by-product of the research rather than the primary aim. The current research would use the information as part of the practical countermeasures that could be considered in the rural environment, but it will not serve as the entire possible set of solutions that are available. Finally, the CDOT product will be a valuable tool for consideration in the current project, but again it is only one small part of the picture.

In reviewing current research, it appears that there is not sufficient information currently available for the rural environment to synthesize or highlight best practices. New research is needed to advance the thinking in this area.

IV. Research Objective

The proposed research will result in a guide that provides guidance and/or warrants on when bicycles should be accommodated on rural highways and suggest sensible accommodation options that are appropriate for the rural environment. Some of the steps or tasks would be as follows:

- Describe the whole set of possible factors that affect bicycle safety and comfort on rural roadways.
- Define scenarios in which bicycles should be prohibited on certain roadways.
- Identify criteria that should be used to determine when a road should be reviewed for possible bicycle-related improvements – vehicle and bicycle volumes, requests from the public, particular groups or organizations.
- Develop a process that can be applied to roads such that a determination can be made as to the objective need for bicycle improvements – i.e. warrants. Ideally, such warrants would be based on a substantive safety analysis if possible. Warrants would also be tied to specific countermeasures, particular the provision of sholders.
- Identify in some priority order the set of countermeasures that are available for use in the rural environment. The detailed descriptions of the countermeasures should provide some information on the relative cost of the countermeasures and their ability to address specific types of safety problems or concerns.
- Provide a process that assists in the selection of practical and cost effective solutions for a given situation.

Some of the items that are relatively important for inclusion in the above are:

- Specification of when paved shoulders should be provided for bicyclists. When are “hard” shoulders sufficient?
- Consideration of constraints – e.g. narrow bridges - on rural roads and their effect on the safety of bicyclists.
- Consideration of rumble strips when accommodating bicyclists.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$350,000
Research Period:	36 months

VI. Urgency, Payoff Potential, and Implementation

Given the increasing use of rural roads by bicyclists in many parts of the country, the nearly complete lack of guidance and information for accommodating bicycles on rural roads and pressure that many road officials experience from community groups and others, the research is considered to be very urgent. The payoff of doing the research an achieving the goals of the project include a better understanding of the problem by road officials, a clearer knowledge of when they should or should not undertake improvements for bicyclists and the extent and scope of the improvements that they should undertake.

The primary product will be a guide that provides guidance and/or warrants on when bicycles should be accommodated on rural highways and suggest sensible accommodation options that are appropriate for the rural environment. Certainly, adoption by AASHTO would be a very useful end goal if the guidance is to be accepted and widely applied by state and local officials with jurisdiction of rural roads. However, it may be unlikely to expect that it will be included separately in any given AASHTO guide, particularly in the short term.

VII. Person(s) Developing the Problem

TBD

VIII. Problem Monitor

TBD

IX. Date and Submitted by

TBD

I. Problem Number 6: Geometric Design Guidelines for Major Intersection Alternatives to Accommodate Multimodal Users

II. Research Problem Statement

Intersections on multilane arterials are becoming increasingly congested throughout the U.S. and other countries. Engineers have few good options to improve these intersections. Turn lanes, actuated signals, and signal systems have usually been employed for years. Widening and structures can be very expensive and environmentally disruptive. Transit, demand management, and intelligent transportation systems are typically years away from making a meaningful impact on the congestion.
In recent years, engineers have begun employing alternatives to conventional intersections as a way to reduce congestion without great expense or other large impacts. Michigan has used the median u-turn design extensively for years, while New Jersey has used the jughandle design. New York and Maryland have successfully employed the continuous flow intersection, while Maryland has also used the superstreet design. Research has shown that there are other designs that could boost efficiency with modest extra cost or other impact, including the quadrant roadway intersection.

The American Association of State Highway Transportation Officials' (AASHTO) Policy on Geometric Design of Highways and Streets contains guidelines on the design of standard intersections and contains some guidance on the median u-turn and jughandle alternatives. However, the guidance provided on the design of median u-turns and jughandles is limited, and there is no guidance from AASHTO, in the Policy or elsewhere, on the other alternatives mentioned above. This lack of guidance is likely discouraging engineers from even considering one or more of the alternatives where they may be appropriate. This, in turn, may lead to suboptimal designs being employed or retained, and more delay and collisions than may otherwise have happened.

III. Literature Search Summary

Most of the previous research on major intersection alternatives has concentrated on travel time and delay for the alternatives in comparison to each other and to conventional designs.

There have been a few papers providing collision frequencies and rates for some of the alternatives. There is practically no literature providing guidance on the details of the designs.

Two recent efforts have summarized the available literature on the alternative designs. The first effort was by the FHWA ("Signalized Intersections: Informational Guide, FHWA-HRT-04-091, dated August 2004, available at www.tfhrc.gov/safety/pubs/04091/). The second effort was by Reid ("Unconventional Arterial Intersection Design, Management and Operation Strategies," dated September 2003, available at www.pbworld.com/library/fellowship/reid/). Both efforts brought together the relatively plentiful past findings on travel time and delay with the relatively sparse past finding on safety. The FHWA material was included in a larger document providing information on many different aspects of signalized intersection design and operation, and thus places the major alternatives in that context. Reid's effort was more focused on the major alternatives, and he summarizes the literature related to several more alternatives than the FHWA effort. On the five major alternatives that have been applied most often in the U.S. and/or have the most potential for travel time savings (median u-turn, jughandle, superstreet, continuous flow intersection, and quadrant roadway intersection) both of these thorough recent reviews provide a fine foundation from which this research can build.

IV. Research Objective

The objective of this research would be to provide guidance on the geometric and traffic control details of the major intersection alternatives. This would include answers to questions such as:

- Where should one locate median openings?
- Where are the best crosswalk locations?
- What are the best median and island treatments?
- What sign designs best convey needed guidance information to unfamiliar drivers?
-

The research should include a review of previous research, although as noted above two recent thorough reviews have been performed and this research should be able to build upon that foundation. The main effort here will be an examination and evaluation of current practices. The researchers will likely need to visit and observe operations at the existing sites where alternatives have been employed. It will probably not be possible to conduct controlled experiments to evaluate the design choices, but the researchers should still be able to collect and analyze data from actual installations pertaining to some of those choices. The researchers may be able to utilize simulations and visualizations to analyze some of the design choices. Focus groups and expert panels of road users and professionals may also be excellent tools in these evaluations. The researchers must consider all expected users of intersections, including pedestrians, bicyclists, trucks, buses, users with disabilities and others. The final report should include proposed changes to AASHTO Policy as well as recommendations for changes in other standard documents like state design manuals. The final report should also provide strategies for how to address important questions on which the quantitative evidence is currently weak.

Much of the experience with major alternatives has been outside the U.S., particularly in Mexico with the continuous flow intersection. Thus, the research effort should include visits and observations of these applications outside the U.S. Projecting how well those international experiences apply to U.S. conditions will be a critical element of the research. It should also be noted that, except where they appear as part of a larger overall scheme (as in the "Bowtie" design) roundabout design and operation are out of the scope of this project. Issues related to roundabout design and operation have been and will be addressed in other research projects.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$400,000
Research Period:	30 months

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics at their combined meeting in June 2004 as being among the top 15 highest priorities for geometric design research. The problem of congested intersections on multilane arterials is serious nationwide and internationally and is getting worse with each year. The research is needed because, besides the designs to be investigated in this project, there are not many good alternatives for efficient and safe ways to improve at-grade intersections. However, many transportation agencies will not use these designs without the guidelines to be supplied during this project. Once the guidelines are distributed to transportation agencies and, perhaps, adopted by AASHTO in some appropriate form, designers should begin earnestly considering all options for intersection improvements.

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IX. Date and Submitted by

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I. Problem Number 7: Ramp Design as a System

II. Research Problem Statement

The American Association of State Highway Transportation Officials' (AASHTO) Policy on Geometric Design of Highways and Streets contains guidelines for the relationship of the ramp design speed to the design speed of the mainline highway as well as guidelines for the design of ramp terminal intersections. However, the design of ramps have not typically been viewed as a related system comprising the ramp exiting roadway, ramp proper, and ramp terminal (or ramp entering roadway for direct connection ramps).
Although ramp design has a major effect on the ability of a freeway to carry traffic safely and efficiently, this is a topic for which there has been little research or literature published. To a certain extent the guidelines in AASHTO are arbitrary, as they are not based on operational conditions experienced on ramp systems. Ramp design practices should be related to driver expectations and behaviors for a range of geometric and traffic conditions including the functional classification of the two interchanging facilities, the interchange form, ramp type, and the area environment (rural vs. urban). A large number of freeway accidents occur at interchange ramps. The issue of ramp design as a system is a complex issue and consequently a candidate for basic research.

III. Literature Search Summary

As noted earlier, there is limited research on the subject area of ramp design as a system. There is a range of research available that addresses ramp design issues, but this research is largely related to one aspect of ramp design (freeway-ramp relationship or ramp terminal design). Much of the recent literature on ramps is summarized in NCHRP Synthesis 299.

IV. Research Objective

The objective of this research is develop ramp system design criteria based on quantitative information obtained from actual field observation, theoretic considerations, simulations, or a combination of the three approaches. Research should highlight the safety, operational, and other issues associated with ramp design dimensions for the full range of interchange forms, ramp types (system and service), and area environments (rural vs. urban).

The research should include a literature review of previous research and current practice in regard to ramp design practices, development of a work plan to achieve the research objectives, collection of applicable field data and other information, evaluation of the safety and operational effects of various ramp designs, and preparation of a final report. The final report should include proposed changes to AASHTO Policy, if results support a change.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$500,000
Research Period:	36 months

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics at their combined meeting in June 2004 as one of the ten highest priorities for research. The research is needed to fill performance gaps in current ramp design practices. It will be of use in the design of highways nationwide.

VII. Person(s) Developing the Problem

TRB Committee on Geometric Design
TRB Committee on Operational Effects of Geometrics

VIII. Problem Monitor

To be determined

IX. Date and Submitted by

To be determined

I. Problem Number 8: Transition Zones—Design from High-Speed to Low-Speed Rural Sections

II. Research Problem Statement

According to the National Highway Traffic Safety Administration, speeding is one of the most prevalent factors contributing to traffic crashes. In 2002, speeding was a contributing factor in 31 percent of all fatal crashes, and 13, 713 lives were lost in speeding-related crashes. Communicating changes in speed environment and drivers' need to adjust their speed is difficult.

Transitioning high-speed rural highways through small rural towns and into the suburban/urban environment is a design challenge. Making the transition safer is an important goal.

AASHTO's Policy on Geometric Design of Highways and Streets (Green Book) contains general guidelines related to taper design when transitioning from two-lane operation to four-lane operation. Transition taper design is a function of speed and the amount of cross-section width being added to or removed from a roadway section. The Manual of Uniform Traffic Control Devices (MUTCD) provides additional information about taper design for passing sections on two-lane highways. We need to figure out better ways of doing it. There is a need to evaluate whether and how combinations of horizontal, vertical alignment and cross section can be used to effectively influence operating speeds.

III. Literature Search Summary

There has been limited research in this subject area. NCHRP Project 15-22 "Safety Consequences of Flexibility in Highway Design," which is nearing completion, was to develop guidance to help project planners and designers estimate the safety consequences of varying designs when flexibility is applied for roads that transition from rural to built-up areas or pass through a built-up area on a predominately rural section of roadway. The study used a case study approach and found, for almost all case studies examined, that the operating speed was higher than the design speed and posted speed through the transition. One general observation from the NCHRP 15-22 case study projects was that most transitions between rural and urban areas took place over relatively short distances (in most cases, only a couple hundred feet, or less). These were inadequate in achieving any real operational speed changes. The study recommends further research to develop better methods and processes for designing transition zones.

The traffic-calming literature (e.g., Publication No. FHWA-RD-99-113 "Traffic Calming: State of the Practice"), while it focuses on urban and suburban applications, includes treatments that might be applied in rural settings. There is considerable experience in Europe with the use of gateways and other treatments to reduce speeds on main rural roads entering built-up areas. Publication No. FHWA-PL-01-026 "Geometric Design Practices for European Roads," summarizes the findings of a joint AASHTO-FHWA scan tour that included several related issues including transition zones.

There is a considerable body of research literature on design speed, operating speed, posted speed, and their interrelationships. Most of the previous research addresses two-lane rural highways, with much more limited literature on the urban environment. No US literature specifically addresses transition zones. NCHRP Report 504 addresses this topic. NCHRP Project 15-25 "Alternatives to Design Speed for Selection of Roadway Design Criteria" is pending.

IV. Research Objective

The objective of this research is develop improved treatments and procedures for designing transitions from high-speed rural highways to lower-speed rural built-up areas and suburban/urban environments. The research should compile existing treatments and methods in the US and other countries, review previous research on their applicability and effectiveness, develop a work plan for the additional research achieve the research objectives, collect applicable field data and other information, analyze the data, and prepare a final report. The final report should include proposed changes to AASHTO Policy, if results support a change.

V. Estimate of Problem Funding and Research Period

Recommended Funding: $500,000
Research Period: 30 months

VI. Urgency, Payoff Potential, and Implementation

This research topic was selected by the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design, and the TRB Committee on Operational Effects of Geometrics during their joint meeting on Strategic Geometric Design Research Needs in June 2004. The research is needed to fill performance gaps in current design policy and practice. It will be of use in the design of highways nationwide. It will yield design treatments and procedures that will impact speed-related crashes, which account for 31 percent of all fatal crashes nationwide.

VII. Person(s) Developing the Problem

TRB Committee on Geometric Design
TRB Committee on Operational Effects of Geometrics

VIII. Problem Monitor

To be determined.

IX. Date and Submitted by

To be determined.

I. Problem Number 9: Design, Safety and Operations of Pedestrian Geometric Intersection Treatments

II. Research Problem Statement

A number of pedestrian treatments have been developed for inclusion in intersection design over the years but research data that provides conclusive information about their effectiveness is lacking. Treatments include intersection geometry (including curb extensions/road narrowing and reduced curb return radius), in-pavement flashers, advance signing, messaging and beacons, signal features, medians and refuge islands, various methods of crosswalk markings (conventional striping, pavement texture changes, raised crosswalks), use of barriers such as fences or shrubs to discourage pedestrians from crossing at unsafe locations, and elimination of roadside obstacles that obscure visibility between pedestrians and vehicles. Roadway designers are consistently faced with making judgments about the safety and viability of pedestrian features at intersections. Transportation agencies, as well as roadway engineers and urban designers, are looking for guidance ~~in~~ about the effectiveness of various pedestrian accommodation treatments.

Often, incorporating features that are perceived to enhance pedestrian comfort and safety can have impacts on the design of the roadway for vehicle operations. An example is reducing the curb return radius to shorten the pedestrian travel at a crossing can have the undesirable effect of impeding right turns by larger vehicles. Inclusion of median refuge areas at intersections can affect left turn operations, and can result in the misalignment of opposing left turning vehicles, compromising sight distance and the view on oncoming traffic.

III. Literature Search Summary

Right-turn interactions and channelized right turns/free-right turn lane design and impacts are the focus of NCHRP 3-72 and NCHRP 3-78, both currently underway. A few studies have been conducted on the effectiveness of in-pavement flashers and advanced warning messages such as “animated eyes”.

There is substantial research that addresses good design practice to accommodate a specific mode but there is nothing found that evaluates the effect of pedestrian treatments on other users of the intersection.

IV. Research Objective

Better information is needed about the effects of pedestrian geometric intersection treatments in enhancing safety, complementing or impeding vehicle operations, and liability impacts to agencies incorporating these treatments. Legal guidance is not proposed. The research should simply identify what potential liability issues might exist. Objectives of the research would include guidance on design of treatments, guidance on the appropriate locations for treatments, and guidance on the trade offs between conflicting pedestrian and vehicle elements. The research should identify and develop a matrix to provide quick reference for responsible implementers on the appropriate use of pedestrian treatments at a variety of locations. Research should also consider the potential conflicts between pedestrian and bicycle treatments that occasionally arise in providing facilities for these modes.

Accomplishment of the project objective will include at least the following tasks:

(1) Review the existing geometric design, and other relevant literature (both domestic and international) to (a) document the current state of practice with respect to pedestrian

geometric intersection treatments, (b) document the safety records of the various treatments, (c) assess the effectiveness of the various treatments in a qualitative manner, both in terms of vehicle operations and pedestrian comfort and safety, (d) assess the effects of crossing distance and curb radius on intersection capacity, vehicle delay and pedestrian and vehicle safety(e) suggest changes to treatments as a result of the research effort.

(2) Select an appropriate number of sites with and without pedestrian safety treatments and conduct field studies that will allow the sites to be compared. Sites should be those utilized by as many different modes as possible and the interactions between the modes should be documented.

(3) Analyze vehicle operations for the above sites and document qualitatively at each location.

(4) Using the information generated in (2) above, model impact on vehicle operations and pedestrian safety with the goal in mind of recommending changes to designs for the treatments and guidance in the appropriateness of their use in a variety of environments.

(5) Submit a final report that documents the entire research effort, recommends design criteria and appropriate application for the pedestrian treatments. The report should comment on the effects of its recommendations on the classes of pedestrians including children, the elderly, and people with disabilities. Where appropriate, the report should include appendices with recommended language for the AASHTO Policy on Geometric Design of Highways and Streets; the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities; and other documents as appropriate.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$300,000
Research Period:	24 months

VI. Urgency, Payoff Potential, and Implementation

State and local transportation agencies, and the design communities that apply their guidance documentation, would use the information obtained from the research project to develop guidelines for the intersection design for various facilities. This would result in a transportation system that better considers all modes and provides the safest design for all users, based on site-specific conditions. Documents that would potentially be affected are the AASHTO Policy on Geometric Design of Highways and Streets; and the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities.

VII. Person(s) Developing the Problem

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VIII. Problem Monitor

IX. Date and Submitted by

November 1, 2004

I. Problem Number 10: Effectiveness of Various Mid-block Crossing Treatments

II. Research Problem Statement

Pedestrians desire to travel from origin to destination in as near a straight line as is possible. When that involves crossing a street or highway, many pedestrians chose to cross at a mid-block location. It has been argued that providing signs and markings gives pedestrians a false sense of security. There is no guarantee that any given driver is aware of the potential pedestrian crossing or, if aware, will exercise any caution regarding the potential crossing. According to the MUTCD, the only way an at-grade crosswalk can exist at a mid-block location is if it is marked. The traditional consensus among traffic engineers is that at-grade mid-block crosswalks are usually undesirable. But both actual pedestrian actions and public demand can create pressures for the installation of a pedestrian mid-block crossing. One alternative, grade separated pedestrian crossings, can be costly and go unused after constructed.

The research should address the following issues.

- The relationship of roadway width, the inclination to cross at mid-block, and the safety of crossing.
- The relationship between the distance to an intersection (to either a signalized or a non-signalized intersection) and the inclination to cross at mid-block.
- Land use and mid-block crosswalk relationships: the way that origins and destinations are placed relative to each other (such as placing a major building entry at mid-block, with a parking lot directly across the street) can create a demand for mid-block pedestrian movements.
- The effectiveness of various mid-block crossings treatments (no treatment, marked, activated flasher, continuous flashers, signal, raised table, grade-separated, and other), both in terms of amount of use, disruption to motorist, and safety.

III. Literature Search Summary

- Walkinginfo.org. In the 1970's, a methodology for typing pedestrian crashes was developed by the National Highway Traffic Safety Administration to better define the sequence of events and precipitating actions leading to pedestrian-motor vehicle crashes. In the early 1990's, this method was refined and used to determine the crash types for more than 5,000 pedestrian crashes in six states. The results showed that the mid-block events were the second major grouping of crash types and accounted for 26.5 percent of all crashes. Among this group, the most commonly crash type (1/3 of all) was the mid-block dash in which the pedestrian ran into the street and the motorist's view was not obstructed. Another 17 percent of these crashes were dart-outs, i.e., the pedestrian ran or walked into the street, but the motorist's view was obstructed until just before the impact.
- "Law Enforcement, Pedestrian Safety, and Driver Compliance with Crosswalk Laws," *Transportation Research Record 1485.* Although not targeted solely at mid-block crossings, a Seattle study found enforcement was rather ineffective in getting vehicles to stop for pedestrians
- *Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations*, FHWA-RD-01-075. A large study based on five years of data at uncontrolled intersections found the presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multi-lane sites with both marked and unmarked crosswalks. Factors having no significant effect on pedestrian crash rate included: area (e.g., residential, central business district [CBD]), location (i.e., intersection vs. mid-block), speed limit, traffic operation (one-way or two-way), condition of crosswalk marking (excellent, good, fair, or poor), and crosswalk marking pattern (e.g., parallel lines, ladder type, zebra stripes).
- *A Review Of Pedestrian Safety Research In The United States and Abroad*, January, 2004 (FHWA-RD-03-042). Summarized research on pedestrian safety in the United States with a focus on crash characteristics and the safety effects of various roadway features and traffic-control devices.
- "Innovative Pedestrian Treatments at Unsignalized Crossings," NCHRP project 3-71, nearing completion at the end of 2004. Stated objectives include finding new engineering treatments to improve safety for pedestrians crossing high-volume and high-speed roadways at unsignalized locations, in particular those served by public transportation; and recommend modifications to the MUTCD traffic signal pedestrian warrant.
- "Planning, Design, and Operation of Pedestrian Facilities," NCHRP project 15-20, nearing completion at the end of 2004. The first objective of this project was to compile the most relevant existing information related to the planning, design, and operation of pedestrian facilities, including the accommodation of pedestrians with disabilities. The second objective was to develop a guide for the planning, design, and operation of pedestrian facilities.

IV. Research Objective

The objective of this research is to identify those factors or situations that are either conducive to or unfavorable for the safe operation of mid-block crosswalks. These should include both pedestrian demand and traffic operations considerations. Planning and land development practices that can reduce demands for mid-block crossings at inherently unsafe locations should be documented.

The project should include a literature review of previous related research, and a documentation of the degree of use and the safety experience of grade-separated crossings compared to at-grade mid-block crossings. The final report should include informal warrants for the installation of grade-separated or at-grade mid-block crossings and level of warning (e.g., basic warning signs and pavement markings for crosswalk, pavement markings in advance of crosswalk, crosswalk with median shelter area, continuous flashing lights, activated flashing lights, pedestrian-activated traffic control signal), and other actions to take to both better serve pedestrians and avoid creating unsafe situations.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$250,000
Research Period:	27 months

VI. Urgency, Payoff Potential, and Implementation

Since there is little research guidance as to the effectiveness of various measures on reducing pedestrian crashes, and more emphasis is given to encouraging short trips to be made by walking, research is needed to provide empirical data to professionals designing streets and highways to safely accommodate both pedestrian and motor vehicle traffic.

This project will provide empirical data in an area where little data is now available and for a situation that results in sizeable proportion of all traffic-related injuries, and can be expected to become increasingly prevalent. The research will be used where there are pedestrian-vehicle conflicts across the nation.

VII. Person(s) Developing the Problem

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VIII. Problem Monitor

TBD

IX. Date and Submitted by

TBD

I. Problem Number 11: Operational and Safety Impacts of Four- and Six-Lane Sections with Raised Medians versus Two-Way Left Turn Lanes

II. Research Problem Statement

Multilane road cross sections are often designed to include some type of median, either depressed, raised, or flush. When a flush median is selected, it often includes a two-way left turn lane (TWLTL). In urban areas, the choice is often between a raised median and a TWLTL. In some instances a designer would prefer a raised median in order to enhance mobility and safety, but abutting property and business owners express a strong preference for TWLTL.

Some have suggested various volume thresholds at what volume to convert from a five-lane design (TWLTL) to a non-traversable (e.g., raised) median. Two concerns about non-traversable median designs are the additional travel distance and time due to the indirection caused by access restrictions, and the safety effects of the increased U-turn demand.

The analysis should consider and differentiate among the following factors.

- Number of through lanes: four or six
- Environment: rural, suburban, urban of various densities
- Volume and speed
- Signal density
- Access type and density

III. Literature Search Summary

Some of the existing studies are limited in scope, or otherwise do not address a full range of conditions and combinations of variables that need to be addressed.

- *Safety Impacts of Selected Median and Access Design Features*. After determining that it was difficult to find suitable study sites, the researchers concluded that restrictive medians (flush grass or raised) were safer than non-restrictive medians.
- *Investigation of The Impact of Medians on Roads Users*, FHWA-RD-93-130. This study examined the safety impact of raised curb medians, TWLTLs, and undivided cross sections on both vehicles and pedestrians in urban environments.
- *Median Intersection Design*, NCHRP Report 375. This report developed guidelines for the selection of median widths for at-grade intersections. It may provide insight into why there might be differences among different raised-median roadways.

- *Access Management Manual.* This manual summarized findings from a number of studies about operational and safety impacts related to access management.
- *Impacts of Access-Management Techniques,* NCHRP Report 420. This report documented the effects of various access management techniques, including median treatments.
- *Safety of U-turns at Unsignalized Median Openings*, NCHRP Project 17-21, draft final report under revision, as of October 2004. This study examined the impact of U-turns on the safety of the road.

IV. Research Objective

The objective of this research is to better document the trade-offs involved with selecting either a raised or a TWLTL median, and differentiate between these effects in a four-lane versus a six-lane environment. The research should also incorporate the effects of different environments, volumes, speeds, signal densities, and access densities.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$350,000
Research Period:	30 months

VI. Urgency, Payoff Potential, and Implementation

Design professionals need empirical data to assess and compare the safety attributes of non-traversable medians versus TWLTL's for both four-lane and six-lane roadways at various volumes, speeds, and other characteristics. The study will help determine under what conditions non-traversable medians should be required and help to sell non-traversable medians to the surrounding community when those conditions exist. With the emphasis on managing and improving traffic flow and safety, the need is urgent and the pay-off is substantial and immediate and applicable nationwide.

VII. Person(s) Developing the Problem

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VIII. Problem Monitor

IX. Date and Submitted by

TBD

I. Problem Number 12: Intersection Design to Accommodate Pedestrian Crosswalk Cross Slope

II. Research Problem Statement

The Americans with Disabilities Act (ADA) requires that public rights-of way, including sidewalks and crosswalks, be accessible to pedestrians with disabilities. The U.S. Access Board's ADA accessibility guidelines specify the minimum level of accessibility in new construction and alteration projects and serve as the basis for enforceable standards maintained by other agencies. ADA guidelines require that the cross slope in crosswalks not exceed 2% measured perpendicular to the direction of pedestrian travel. Many transportation agencies are looking for guidance on working with these proposed provisions.

Many of the potential treatments used to achieve the required cross slope on crosswalks will not conform to existing highway design and construction standards. In addition, tabling the crosswalk or intersection would require adjustments in the vertical alignment of the roadway which would impact street drainage. Tabling crosswalks or intersections may also have unintended negative impacts on the control and safety of motor vehicles and their occupants. These concerns are heightened for emergency vehicles. Loss of control of vehicles in urban areas could have tremendous safety implications for pedestrians alongside the roadway.

III. Literature Search Summary

A search of TRIS online and the Research in Progress databases did not identify any research specifically addressing the interaction between roadway design and pedestrian crosswalk cross slopes.

IV. Research Objective

Better information is needed about the introduction of reduced street grades at pedestrian crosswalks for roadways on steep longitudinal grades. Since the cross slope of the crosswalk is also the longitudinal grade of the street being crossed, this requirement impacts the vertical alignment of the roadway in the vicinity of the intersection. The impact of tabling intersections on motorist safety and street drainage needs to be examined and potential platform designs to safely accommodate vehicles on streets with steep grades, while meeting the crosswalk cross slope requirements, need to be developed.

Accomplishment of the project objective will include at least the following tasks:

(1) Review the existing geometric design, hydraulic design, and other relevant literature (both domestic and international) to (a) Document the current state of practice with respect to tabled intersection design, drainage, vehicle dynamics and the safety of users of all modes, (b) document the safety of various designs on the various modes, and (c) determine engineering policies and practices that may need to be revised as a result of the anticipated recommendations from this research effort.

(2) Select an appropriate number of sites with and without tabled intersections and conduct field studies. Sites should be those utilized by as many different modes as possible and the interactions between the modes should be documented.

(3) Analyze accident/crash reports for the above sites and document the number and type of accidents and the modes involved at each location.

(4) Simulate the impact on various modes for different designs of tabled intersections and develop recommendations for design policy.

(5) Submit a final report that documents the entire research effort, recommends design criteria for intersection design on various classes of roadways and in various types of terrain, and includes the products of Tasks 1 through 4. Where appropriate, the report should include appendices with recommended language for the AASHTO Policy on Geometric Design of Highways and Streets; the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities; and other documents as appropriate.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$500,000
Research Period:	24 months

VI. Urgency, Payoff Potential, and Implementation

State and local transportation agencies would use the information obtained from the research project to develop guidelines for the intersection design for various facilities and with varying terrain conditions. This would result in a transportation system that better considers all modes and provides the safest design for all users, based on site-specific conditions. Documents that would potentially be affected are the AASHTO Policy on Geometric Design of Highways and Streets; and the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities.

VII. Person(s) Developing the Problem

Elizabeth Hilton - Texas Department of Transportation
Dan Dawson – Otak, Inc.

VIII. Problem Monitor

IX. Date and Submitted by

November 1, 2004

I. Problem Number 13: Horizontal Curve Design

II. Research Problem Statement

While recent research and synthesis efforts have examined/reported on individual design elements of horizontal curves, neither a generalized safety relationship between radius of curvature and design speed nor a comprehensive study of the "minimum radius" model has not been conducted since its initial adoption by The American Association of State Highway Transportation Officials' (AASHTO). Research is needed to more fully address the safety and operational issues related to the geometric design procedures for horizontal curves. The principal knowledge gaps include:

- Definitive data on a relationship between the distribution of available side friction factors (pavement type/conditions) and net accelerations (longitudinal, lateral and vertical) by different vehicle classes (large vehicle {SUVs, trucks, buses} overturning/rollover thresholds), tire properties, and curvature classes.
- Appropriateness of the minimum radius equation to capture the relationships/interactions of vehicle characteristics (over simplification of the "point-mass" model), driver's human factors tolerances (e.g., acceleration limits, rollover potentials, reaction times), operating conditions on various functional classes of roadways, roadway elements (turning roadways, interchange ramps, at-grade intersection turning radii), effects of vertical alignments, and respective vehicle operating speeds approaching and through the actual accommodated horizontal curves.
- Sight distance consideration on alignments where combined horizontal, vertical and cross sectional elements are present.
- Safety performance measurements and collision prediction models for curved roadway segments.

III. Literature Search Summary

Research efforts that are either recently completed or are currently underway that relate to the problem statement include:

- NCHRP Synthesis 299, *Recent Geometric Design Research for Improved Safety and Operations*, cites various studies addressing horizontal curve designs for safety and operational issues associated with passenger cars and trucks.
- NCHRP Report 439, *Superelevation Distribution Methods and Transition Curves*, recommended changes to the distribution of lateral acceleration via Superelevation transitions on roadway sections between tangent alignments and a horizontal curve.
- NCHRP Report 500 -- *Volume 7: A Guide for Reducing Collisions on Horizontal Curves* provides general guidance on improving or restoring superelevation and modifications to horizontal curvature.

- Ongoing research via NCHRP Project 15-25, *Alternatives to Design Speed for Selection of Roadway Design Criteria* is envisioned to provide guidance on the selection of "design" speed for various geometric design elements.

IV. Research Objective

The principal research objectives include:

1. Validation and appropriateness of current limiting values used in horizontal curve designs.
2. Identification and implications of the pertinent safety relationships associated with the respective limiting values.
3. Development of alternative horizontal design formulae, models or criteria based upon the resulting validation and safety findings.
4. Testing and calibration of the recommended horizontal curve design criteria, policies or procedures.

This research should assess the limiting values currently used in current AASHTO policy for superelvation rates and side friction demands. The study would consider the broad range of vehicles, various functional classes of roads and streets and commensurate operating speeds. Research activities would represent observed in-field conditions, closed track data, model simulation/calibrations and laboratory testing/validation. Collected data would represent the continuum of driver/vehicle/roadway characteristics and would represent horizontal curve designs across the range of high speed and low speed alignments. Research is particularly needed for operating speeds below 60 mph (100 km/h) due to increased attention to context sensitive design situations. Statistical modeling, simulation, and other experimental methods should all be considered as viable research methodologies. The research data would be analyzed to determine if the basic, "minimum radius equation" formula and respective parameter assumptions are appropriate for current and anticipated vehicle fleet and operating conditions.

Regardless of the resulting findings, i.e., that all current horizontal curve design conditions are found to be valid, or new alternative design methods are recommended, it is envisioned that both safety and economic evaluations be established to assess the application/implementation of the findings and potential recommendations. The safety and economic analyses will assist practitioners in assessing trade-offs of various horizontal curve design decisions.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	$1 to 1.5 million to address the full range of horizontal curve applications e.g., road/street segments, ramps, turning roadways and turning radii for at-grade intersections. The funding could be segmented/prioritized by roadway functions and/or design elements.

Research Period: 48 months for full range of applications. Likewise, if funding is partitioned, then research periods could be adjusted accordingly.

VI. Urgency, Payoff Potential, and Implementation

This research topic was ranked among the highest priorities at the joint meeting (June 2004, Williamsburg, VA) of the AASHTO Technical Committee on Geometric Design, the TRB Committee on Geometric Design and the TRB Committee on Operational Effects of Geometrics. The implications are broad ranging and will directly assist designers in addressing new, reconstructed and context sensitive design situations across various functional classes of roads and streets. The findings will also provide the necessary guidance to accommodate various vehicle classes while considering safety and economic issues associated with horizontal curve designs. Urgency is high and the potential payoff of this research is substantial. The implementation would be via the AASHTO Geometric Design Policy, the Interactive Highway Design Safety Model, the AASHTO guide for Achieving Flexibility in Highway Design, the developing Highway Safety Manual, and other state and local geometric design standards.

VII. Person(s) Developing the Problem

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VIII. Problem Monitor

TBD

IX. Date and Submitted by

TBD

I. Problem Number 14: Median Design and Barrier Considerations for High-speed Divided Highways in Rural and Urban Areas

II. Research Problem Statement

The American Association of State Highway Transportation Officials' (AASHTO) Roadside Design Guide (RDG) contains median barrier warrant criteria. The existing criteria consider both median width and average daily traffic volumes as decision-making variables and have not changed since the 1970's. National Cooperative Highway Research Program (NCHRP) project 17-14 "Improved Guidelines for Median Safety" is using roadway cross-section and crash data to evaluate the appropriateness of these criteria. The RDG also contains guidelines regarding longitudinal barrier type and placement guidelines for median applications; however, additional guidance is needed to determine which median barrier systems provide the best safety performance and are most cost-effective given a set of field parameters.

The AASHTO Policy on Geometric Design of Highways and Streets (herein referred to as the Green Book) also contains general median width and median side-slope design guidance that has remained unchanged for many years. Since the vehicle fleet, travel speeds, and traffic volumes have changed dramatically, there is a need to better understand the vehicle dynamics associated with median crossover crashes on high-speed highways in rural and urban areas. Design guidance is needed to supplement median barrier warrant criteria to include the influence of horizontal and vertical alignments; the presence, configuration, and traffic characteristics of interchange entrance ramps; and, variations of median side slopes on median-related crashes. For instance, it is important to know if flattening median side slopes reduces the frequency and severity of single-vehicle median-related crashes at the expense of increasing the frequency and severity of multiple-vehicle median-related crashes (i.e., crossover crashes). NCHRP Project 17-14 conducted a before-after evaluation of slope flattening projects in one state; however, a larger sample of depressed median cross-section designs and profiles should be considered. The influence of median surface conditions (e.g., soil type, wet or snow-covered conditions, landscaping) and drainage in depressed medians has not been evaluated and should also be considered to enhance the design-decision process.

In addition to the design guidelines cited, there is a need to better understand median barrier type and placement decisions. Once all of the median design-safety parameters are well-understood, benefit-cost ratios of barrier type and placement guidelines would assist designers in making cost-effective decisions.

In summary, an application tool (Roadside Safety Analysis Program) is available for designers to assess roadside safety design decisions. A similar tool, however, is not available for assessing the cost-effectiveness of median design and barrier installation decisions. Median barrier warrant criteria have been developed to assist designers in determining the need for longitudinal barrier to prevent median crossover crashes. These criteria should be supplemented with additional guidelines that can be used by engineering professionals to determine the safety and cost-effectiveness of various design alternatives on high-speed divided highways.

III. Literature Search Summary

Research efforts that are either completed or are currently underway that relate to the problem statement include:

NCHRP Project 17-14 "Improved Guidelines for Median Safety." This project is using median cross-section and crash data to assess the efficacy of the existing median barrier warrant criteria contained in the AASHTO RDG.

NCHRP Project 17-11 "Determination of Safe/Cost Effective Roadside Slopes and Associated Clear Distances." While this effort is focused on the roadside area to the right of the travel lanes, its applicability to medians on divided highways should be considered. The objective of this research is to develop relationships between recovery-area distance and roadway and roadside features, vehicle factors, encroachment parameters, and traffic conditions for the full range of highway functional classes and design speeds.

NCHRP Project 22-12 "Guidelines for the Selection, Installation, and Maintenance of Highway-Safety Features." The objective of this research is to develop improved guidance for the selection, installation, and maintenance of highway-safety features based on the performance concept. Specifically, the research will address (a) selecting the appropriate highway-safety feature given the characteristics of a site, (b) installing highway-safety features, (c) maintaining highway-safety features to ensure effectiveness over time, and (d) upgrading existing highway-safety features and justifying design deviations or field modifications. This effort was focused primarily on roadside features to the right of the travel lanes and not on the median of divided highways.

NCHRP Report 492 "Roadside Safety Analysis Program – Engineers Manual." This project developed a program to evaluate the cost-effectiveness of roadside safety features. It is intended for single-vehicle run-off-the-road crashes and is not suitable for determining cost-effective median design and barrier installation decisions.
A Federal Highway Administration report (FHWA-RD-97-106) titled "Statistical Models of Accidents on Interchange Ramps and Speed Change Lanes" suggests that ramp traffic volumes explain much of the variability in crashes at interchange locations. The area type, mainline traffic volume, ramp configuration, and ramp/speed change lane lengths were also considered in the analysis.

Several state transportation agencies, including California, Florida, North Carolina, Pennsylvania, and Washington have conducted safety and cost-effectiveness evaluations of median crossover crashes. Although these efforts have focused primarily on median width and traffic volumes, they do contain median-involved crash statistics.

IV. Research Objective

One objective of this research is to determine the influence that various median design variables have on safety. Horizontal and vertical alignment, interchange presence, median width, traffic volumes, and median side slopes must all be considered. Median soil conditions and landscaping should also be considered in the research. It is envisioned that statistical modeling, simulation, and other experimental methods should all be considered as viable research methodologies. Economic evaluations should be considered to verify that the analytical outcomes are feasible. Practitioners would then be able to assess the safety trade-offs of various design decisions.

A second objective is to determine the safety and cost-effectiveness of various median barrier type and placement guidelines. Future research should clearly outline the economic feasibility of various barrier installations given a set of field parameters. For instance, it is important that barriers be located such that when redirecting vehicles, a subsequent high-speed crash does not occur. The barrier height and placement guidelines should not restrict stopping sight distance. Practitioners would also benefit from guidelines outlining how various barriers performed during impact given a set of field conditions (e.g., median cross-section design, weather conditions, landscaping, etc.). A systematic procedure for designers to make median barrier type and placement decisions is needed.

To accomplish the research objectives, the following tasks should be completed:

Literature review of previous research to identify design variables that influence median safety, statistical models of median-related crashes, roadside safety guidelines, and median barrier performance information.

Describe methods that could be used to better understand the dynamic associated with median-related crashes as they relate to median design variables, traffic characteristic and/or driver performance. Include methods for crossover crashes and single-vehicle crashes with median barriers, rollovers, and other crash types. A procedure to identify the frequency of median excursions that do not result in a reportable crash should also be considered.

Describe methods that could be used to improve guidance related to median barrier type and placement guidelines. Longitudinal barriers located at the center of the median, near the edge of the inside (median side) shoulder, and other locations in between should all be considered. Possible methods include an in-service performance evaluation or cost-effectiveness analysis using safety and roadway inventory data, among others. All of the approved barriers in the AASHTO RDG should be considered as should other barrier systems that are gaining nationwide appeal (e.g., Brifen Wire Rope Safety Fence).

Prepare a work plan, with estimated costs, that outlines the various methods being considered. This includes, but is not limited to, vehicle simulation, field data collection and analysis, finite element modeling, and cost-effectiveness evaluation. The intent of this task is to provide the panel with information that can be used to determine which evaluation methods are most feasible for the project.

Submit an interim report to the panel containing all of the elements described in tasks (1) through (4). Meet with the panel to review the report and discuss the second project phase.

Execute the work plan that is agreed to by the panel.
Prepare and submit a draft final report outlining the findings of the research. This document should contain a decision-making methodology that practitioners can use to evaluate various median designs, including barrier type and placement guidelines. A procedure to select the most appropriate longitudinal barrier based on the median width and placement location must be included in the design-decision procedure. Case studies describing the performance of various median barrier systems should also be included, especially for those barrier systems that are not yet included in the AASHTO policy.

Meet with the panel to discuss the draft final report and findings from the research.

Submit the final report.

V. Estimate of Problem Funding and Research Period

Recommended Funding:	It is anticipated that the research outlined in step V above would cost approximately $800,000. This includes $500,000 to accomplish the first objective and $300,000 to accomplish the second objective.
Research Period:	It is anticipated that the research described would take approximately 42 months to complete.

VI. Urgency, Payoff Potential, and Implementation

The urgency and potential payoff of this research is very high. Various state transportation agencies are being pressed to consider revised median designs or installation of median barriers on divided highways to prevent severe, high-speed median-related crashes. Although NCHRP Project 17-14 is intended to update the existing AASHTO RDG median barrier warrant criteria, there is additional research needed to supplement the revised warrants. The economic benefit of preventing median-related fatalities could be very high if an systematic procedure is developed to assist designers in determining where longitudinal barrier should be located once the decision is made to install it.

It is recommended that this research developed a protocol that designers can use to evaluate median design and median barrier placement decisions. This procedure should be included in the AASHTO RDG and could also be included in future versions of the Roadside Safety Analysis Program (RSAP).

VII. Person(s) Developing the Problem

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VIII. Problem Monitor

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IX. Date and Submitted by

TBD

I. Problem Number 15: Right-Turn Interactions and Channelized Right-Turns

II. Research Problem Statement

The Americans with Disabilities Act (ADA) requires that public rights-of way, including sidewalks and crosswalks, be accessible to pedestrians with disabilities. The U.S. Access Board's ADA accessibility guidelines specify the minimum level of accessibility in new construction and alteration projects and serve as the basis for enforceable standards maintained by other agencies. On June 17, 2002, the U.S. Access Board published draft rights-of-way guidelines (Docket No. 02-1) proposing to require pedestrian signals at channelized turn lanes that would create and identify gaps in the vehicle stream adequate for pedestrians who are crossing without vision cues. Many transportation agencies are looking for guidance on working with these proposed provisions.

Better information is needed about the effects of channelized right-turn lanes on urban streets on motorist (cars, trucks and busses), pedestrian, and bicyclist safety. Many agencies use channelized right-turn lanes to improve operations at urban intersections, particularly on urban arterials. Previous research found no reliable evidence to verify the assumption that channelized right-turn lanes provide safety benefits to both motor vehicles and pedestrians. Since concerns about the accessibility of these turn lanes to pedestrians with vision impairments have arisen, research is needed to determine whether channelized right-turn lanes do or do not enhance safety for motorists, pedestrians and bicyclists. In addition, where a channelized right-turn lane is provided, there are differences of opinion about where the striped crosswalk, if provided, should be located. Some advocate putting it near the entry of the channelized right-turn lane so pedestrians are more in the field of vision for approaching drivers. Others advocate putting the crosswalk near the end of the channelized right-turn lane because visually impaired pedestrians will tend to cross the right-turn lane close to the parallel flow of traffic.

Research in NCHRP Project 3-78 will be investigating crossing solutions for pedestrians with vision impairments at channelized right-turn roadways. Whatever the degree of success of that research, which has just begun, one response of highway agencies to the forthcoming regulation may to be remove existing channelized right-turns and avoid constructing new ones. There are no reliable data on whether such actions would be positive or negative for overall safety.

III. Literature Search Summary

In NCHRP Project 3-72, “Lane Widths, Channelized Right Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas”, design guidance and criteria are being developed for addressing the safety and operational tradeoffs for motorists, pedestrians, and bicycles for two specific topics: selecting lane widths and using right-turn deceleration lanes at driveways and unsignalized intersections. Sufficient funds were not available to address the subject of right-turn interactions and channelized right-turns in that project.

Research in NCHRP Project 3-78 will be investigating crossing solutions for pedestrians with vision impairments at channelized turn lanes and roundabouts. However, that project will not look at the more fundamental question of whether the provision of channelized right-turn lanes actually improves safety as has been historically assumed.

A search of TRIS online and the Research in Progress database identified a paper presented at the 1999 Urban Street Symposium and published in e-Circular E-C019. The paper by Dixon, Hibbard, and Nyman entitled “Right-Turn Treatment for Signalized Intersections” makes some comparison of vehicular safety for various right-turn designs but it does not address the safety of other users with respect to the design of right-turn lanes.

IV. Research Objective

The objective of this research is to recommend whether design policy related to right-turn design should be modified, based on the safety impacts of various designs upon different user groups. Exploration of the proper balance among the needs of passenger cars, trucks, busses, pedestrians (including pedestrians with vision impairments), and bicycles is central to achieving the objectives of the research. Accomplishment of the project objective will include at least the following tasks.

(1) Review the existing geometric design, traffic control, and other relevant literature (both domestic and international) to (a) Document the current state of practice with respect to pedestrian, bicycle and vehicular control at channelized right-turn lanes, (b) document the safety of various designs on the various modes, and (c) determine engineering policies and practices that may need to be revised as a result of the anticipated recommendations from this research effort.

(2) Select an appropriate number of sites with and without channelized right-turn lanes and conduct field studies. Sites should be those utilized by as many different modes as possible and the interactions between the modes should be documented.

(3) Analyze accident/crash reports for the above sites and document the number and type of accidents and the modes involved at each location.

(4) Simulate the impact on various modes for different designs of channelized right-turn lanes and develop recommendations for design policy.

(5) Submit a final report that documents the entire research effort, recommends design criteria for right-turn lanes on various classes of roadways, and includes the products of Tasks 1 through 4. Where appropriate, the report should include appendices with recommended language for the AASHTO Policy on Geometric Design of Highways and Streets; the AASHTO Guide for the Planning, Design, and Operation of Pedestrian

Facilities; the AASHTO Guide for the Development of Bicycle Facilities; and other documents as appropriate.

V. Estimate of Problem Funding and Research Period

Recommended Funding: $500,000
Research Period: 24 months

VI. Urgency, Payoff Potential, and Implementation

State and local transportation agencies would use the information obtained from the research project to develop guidelines for the design of right-turn lanes considering all modes of travel and several types of vehicles. This would result in a transportation system that better considers all modes and provides the safest design for all users, based on site-specific conditions. Documents that would potentially be affected are the AASHTO Policy on Geometric Design of Highways and Streets; the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities; and the AASHTO Guide for the Development of Bicycle Facilities.

VII. Person(s) Developing the Problem

TRB Committee on Geometric Design in coordination with the AASHTO Technical Committee on Geometric Design:
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Karen Dixon – Georgia Institute of Technology

VIII. Problem Monitor

TBD

IX. Date and Submitted by

September 1, 2004