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# RESEARCH PROBLEM STATEMENTS—OPERATIONAL EFFECTS OF GEOMETRICS

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OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

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## INTRODUCTION

Committee A3A08, Operational Effects of Geometrics, regards identifying research needs and communicating them to the transportation research community as one of its major functions. The committee has regularly evaluated and published research problem statements in the past, and the publication of this circular is a continuation of that activity.

## EVALUATION METHOD

The committee received eight research problem statements for evaluation during 1982. These research problem statements were circulated to the committee membership, who were asked to evaluate each of them for perceived importance, for allocation of a hypothetical research budget, and for probability of success. The members were also asked to provide a brief rationale for each evaluation. Twenty-four committee members responded to this request. The results were summarized in such a

manner that the anonymity of the respondents was maintained, and the summary was distributed to the entire committee.

EVALUATION RESULTS

The evaluation results showed a great diversity among the committee members in their assessment of the individual problem statements. On a scale from 1 to 8, every problem statement was ranked relatively high in perceived importance (1 or 2) by at least one reviewer and relatively low (7 or 8) by at least one reviewer. The average probability of success anticipated for the problem statements ranged from 50% to 79%.

The evaluation results were discussed at the committee's meeting during the TRB Annual Meeting in January 1983. A decision was reached to publish seven of the eight problem statements that had been evaluated. The author of each problem statement was then asked to make appropriate revisions, taking into consideration the reviewers' comments on the problem statements. The seven research problem statements selected by the committee are presented below.

RESEARCH PROBLEM STATEMENTS

Problem No. 1

1. TITLE: Relation of Roadway and Intersection Geometrics to Signal Coordination.

2. STATEMENT OF PROBLEM: There is increasing interest in improving traffic flow, and in the attendant improvements in capacity and safety, by coordinating signals along urban and suburban traffic corridors. The availability of equipment such as time-based coordinators and cable-television lines makes such coordination very practical. However, the full benefits of signal coordination may not be realized if appropriate roadway and intersection geometric improvements are not also made.

3. OBJECTIVE: The study objective would be to provide procedures that would lead to the determination of various geometric features (e.g., number and width of traffic and turn lanes, median width and type, two-way left-turn lanes, reversible lanes, parking controls) that should be considered in conjunction with signal coordination. The procedures could be used to evaluate alternative improvement schemes and provide information useful in selling the proposed improvement to decision makers.

   Past research efforts in related subject areas should be integrated into this study to put such information together in a usable format. Computer simulation, supplemented by necessary field study, could be used to analyze the benefits of such improvements, not only in the broad terms of optimizing capacity and safety but also in other areas such as reductions in time delays, fuel consumption, and vehicle emissions.

4. KEY WORDS: Signal coordination; time-based coordinators; corridor improvements; lane usage; roadway and intersection geometrics.

5. RELATED WORK:

   a. Development of Warrants for Left-Turn Lanes; Kentucky Department of Transportation, Research Report 526, July 1979;

   b. Evaluation of Reversible Lanes; Kentucky Department of Transportation, Research Report 549, July 1980;

   c. Optimal Signal Timing for Arterial Signal Systems; FHWA-RD-80-082, December 1980;

   d. Synthesis of Safety Research Related to Traffic Control and Roadway Elements; FHWA-TS-82-232 and 233, December 1982.

6. URGENCY/PRIORITY: The increase in signal coordination work and TSM-type projects makes it urgent that definitive procedures be available to determine and analyze alternative improvement schemes to assure appropriate roadway and intersection geometric features are provided with signal coordination efforts.

7. COST: $150,000

8. USER COMMUNITY: Agencies and personnel responsible for the design and operation of highways in urban and suburban high traffic volume corridors.

9. IMPLEMENTATION: The results of this research could be implemented through the publication of procedures and perhaps the identification of appropriate computer models and simulation programs.

10. EFFECTIVENESS: Implementation of the project results should aid users by improving safety and capacity as well as in achieving other ancillary benefits. It would help prevent geometric deficiencies or bottlenecks from negating the potential benefits of coordinated signals.

Problem No. 2

1. TITLE: Traffic Operational and Safety Effects of the Interaction of Lane and Shoulder Width.

2. STATEMENT OF PROBLEM: Separate research has been performed to investigate the effect of lane and shoulder width on traffic operations and safety. The unsolved fundamental question is whether different lane width and shoulder width combinations having the same total roadway width affect traffic operation and safety similarly or differently under various roadway width, traffic, geometric, and land use conditions.

3. OBJECTIVE: The study objective is (1) to quantify the interaction effect of lane and shoulder width on traffic operations, capacity, and safety under various pavement width and roadway traffic, geometric, and land use characteristics, and (2) to recommend cost-effective combinations of lane and shoulder width in a simple and practical

manner under various pavement width and roadway traffic, geometric, and land use characteristics.

4. KEY WORDS: Lane width; shoulder width; pavement width; interaction; traffic operations; and safety.

5. RELATED WORKS: There are several past studies on the effect of lane and shoulder width on traffic operations and safety and a synthesis of these studies has recently been published (1-4). It is generally agreed that the increases in lane and shoulder width improve traffic operations and safety. It is also reported that there appears to be a significant interaction between lane and shoulder width (5). However, no comprehensive study with sound experimental design, proper field data, and analysis has been performed to quantify the operational and safety effects of the interaction of lane and shoulder width.

6. URGENCY/PRIORITY: Since highway agencies are faced with limited right-of-way and resource requirements, the optimum lane and shoulder width combinations should be available for cost-effective road design, particularly for 3R projects.

7. COST: $180,000 over an 18-month period.

8. USER COMMUNITY: Agencies and personnel responsible for highway design and operational and safety improvements.

9. IMPLEMENTATION: The results of this research will be immediately usable by governmental agencies in selecting a cost-effective lane and shoulder width and improving traffic operations and safety.

10. EFFECTIVENESS: The results of this research will be most effective in trade-off analysis and the selection of optimal lane and shoulder width under various right-of-way and roadway traffic, geometry, and land use characteristics.

REFERENCES


1. Roy Jorgensen Associates, Cost and Safety Effectiveness of Highway Design Elements, NCHRP Report 197, TRB, 1978.

2. Texas Transportation Institute, Synthesis of Safety Research Related to Traffic Control and Roadway Elements, FHWA-TS-82-232 and 233, December 1982.

3. Clinton L. Heimbach, Paul D. Cribbins, and Myung-Soon Chang, The Effect of Reduced Traffic Lane Width on Traffic Operations and Safety for Urban Undivided Arterials in North Carolina, Highway Research Program, North Carolina State University, 1980.

4. D. B. Fambro, D. S. Turner, and R. O. Rogness, Operational and Safety Effects of Driving on Paved Shoulders in Texas, FHWA-TX-81/31-265-2F, Texas Transportation Institute Research Report 165-2F, Texas A&M University, 1981.

5. Charles V. Zegeer, Robert C. Deen, and Jesse G. Mayes, Effect of Lane and Shoulder Widths on Accident Reduction on Rural, Two-Lane Roads, TRR 806, TRB, 1981.


Problem No. 3

1. TITLE: Effectiveness of Roadside Design Improvements on Horizontal Curves.

2. STATEMENT OF PROBLEM: Previous research has found that roadside design improvements (flattening slopes, removing fixed objects, etc.) are often not cost-effective on rural highways, except under high traffic volume conditions. However, the literature also suggests that the frequency and severity of fixed object accidents is higher for fixed objects located on the outside of horizontal curves than on tangents. This effect needs to be quantified so that it can be considered in the design process.

3. OBJECTIVE: The objective of the suggested research is (1) to determine whether there are differences between tangents and horizontal curves in the frequency and severity of single-vehicle run-off-road accidents; (2) to quantify these differences in a form useful to the designer; and (3) to suggest practical procedures for including these findings in the design process. The scope of the research should include both two-lane highways and freeways and should consider the effects of both fixed objects and embankment slopes. Two specific design issues should be addressed in the research:

   - Should clear-recovery zones by provided on horizontal curves on some highways where they are not provided on tangents?
   - Should clear-recovery zones provided on horizontal curves be wider than clear-recovery zones on tangents?

4. KEY WORDS: Roadside design; roadside safety; horizontal curves; embankment slopes; and fixed objects.

5. RELATED WORK:


   a. American Association of State Highway and Transportation Officials, "Guide for Selecting, Locating and Designing Traffic Barriers--1977," Washington, D.C. 1977.

   b. Cleveland, D. E and Kitamira, R., "Macroscopic Modeling of Two-Lane Rural Roadside Accidents," Transportation Research Board 681, 1978.

   c. Glennon, J. C., "Roadside Safety Improvement Programs on Freeways--A Cost-Effectiveness Priority Approach," NCHRP Report 148, 1974.

   d. Graham, J. L., and Harwood, D. W., "Effectiveness of Clear Recovery Zones," NCHRP Report 247, May 1982.

   e. Hall, J. W. and Mulinazzi, T. E., "Roadside Hazard Model," Transportation Research Record 681, 1978.

6. URGENCY/PRIORITY: The suggested research is needed to determine whether increased safety benefits could be achieved by focusing the funds available for roadside improvements on horizontal curves.

7. COST: $300,000 over 2 years.

8. USER COMMUNITY: The user community for this research would be all agencies responsible for construction or reconstruction of rural highways.

9. IMPLEMENTATION: The research results would be implemented in the short-term through publication and circulation of the research report. In the long term, the results could be implemented through incorporation in FHWA guidelines and/or in AASHTO policies.

10. EFFECTIVENESS: Implementation of the project results would help users maximize the safety benefits obtained from roadside design improvements by investing available funds where they will do the most good.

Problem No. 4

1. TITLE: Four-Lane Undivided Highways as an Alternative to Two-Lane and Four-Lane Divided Designs.

2. STATEMENT OF PROBLEM: There is no clear cut point at which a two-lane highway should become a four-lane undivided or divided facility. Capacity manuals provide information about lane capacities, etc.; design manuals give a broad range of traffic volumes to consider when designing four-lane divided facilities. While design and capacity criteria are useful, there are instances when economics must also enter the picture. For example, Texas has converted several of its two-lane highways to four-lane undivided facilities by utilizing existing pavement and shoulders. This has been called a "poor-boy conversion".

3. OBJECTIVE: Because there seems to be no definite point at which a roadway should become a four-lane facility nor at which a four-lane facility must be divided, this study should determine:

   a. The cost-effectiveness of construction of a four-lane undivided facility where the measures of effectiveness are safety and level of service.

   b. The cost-effectiveness of construction of a two-lane facility with full-depth surfaced shoulders designed for ultimate conversion to a four-lane undivided highway simply by striping.

   c. The environmental effects on adjacent land and development of two-lane, four-lane undivided and four-lane divided alternatives and a method for evaluating the interrelationships of construction costs with environmental effects.

4. KEYWORDS: Two-lane facilities with full depth; full-width shoulders; four-lane undivided highways; capacity; traffic safety; and economics.

5. RELATED WORK: A Highway Research Information Service search conducted on this topic identified the following sources that might be of assistance in this study:

   a. "National Highway Inventory and Performance Summary--From the 1976 National Highway Inventory and Performance Study-No. FHWA-PL-78-006; Dec. 77 Final Report (statistics only)"

   b. "Report of Committee on Highway Traffic Analysis," G. E. Hamlin, HRB Proceedings No. 26; Vol. 15, Pt. 1. (Suggests going directly from two-lane to four-lane rather than a three-lane facility).

   c. "Accident Analysis for Program Planning," R. E. Jorgensen, HRB Proceedings No. 49, Vol. 29, pp. 336-348. (This study pertains to accident rates for various design standards, volumes, etc.).

   d. "Report of Committee on Highway Traffic Analysis," G. E. Hamlin, HRB Proceedings Vol. 8; pp. 81-98 (Conclusions of the Committee concerning roadway width and traffic capacity are presented).

   e. "Report of Committee on Highway Traffic Analysis," G. E. Hamlin, HRB Proceedings Vol. 7; Part 1 pp. 229-247 (The report also presents some studies of time rate and capacity for two-lane, three-lane, and four-lane roadways).

   f. "Traffic Capacity", A. N. Johnson, HRB Proceedings Vol. II, Pt. 1, pp. 409-412 (A research project to determine capacity of two, three and four-lane roads -- no consideration given to the relative safety of various numbers of lanes and median designs under varying volumes of traffic).

   g. "Effects of Paved Shoulders on Accident Rates for Rural Texas Highways", D.S. Turner; Fambro, D. B.; Rogness, R. O.; Transportation Research Record 819; 1981, pp. 30-37 (A study of accident rates and characteristics were compared for three different types of rural Texas highways: two-lane roadways with and without paved shoulders, and four-lane undivided roadways without paved shoulders).

   Despite these sources identified by the HRIS search, there still seems to be no definitive information to indicate when it is cost-effective to go from a two-lane facility to a four-lane undivided roadway and perhaps eventually to a multi-lane divided facility.

6. URGENCY/PRIORITY: As a matter of economics, it is our responsibility as engineers to design and construct the most cost-efficient facility. This is urgent since it is imperative that we reconstruct our highways to the safest and best facilities possible with the revenue available.

7. COST/TIME: This project, using as much previous research data as possible, should cost

no more than $100,000 and should be accomplished in 12 months.

8. USER COMMUNITY: The principal users of this study will be highway designers and administrators.

9. IMPLEMENTATION: The study results may cause some rethinking by designers. If a four-lane undivided facility can be built to adequately accommodate traffic and increase highway safety for considerably less money than alternative designs, then the study results should be implemented as soon as possible.

10. EFFECTIVENESS: If the study results show the four-lane undivided facility to be a priority alternative, then constructing such highways should be effective, since more miles can be built for the same cost.

Problem No. 5

1. TITLE: Geometric Design Requirements for Low-Speed Maneuvers.

2. PROBLEM: Intersecting urban streets or streets and driveways are typically provided with single-radius curves in the 15- to 30-foot range. These radii typically support relatively low speeds, and when combined with less than normal approach lane or exit throat widths, they can cause turning motorists to swing out before starting the turn. This conflicting movement is sometimes the cause of accidents and does impact on the operation of higher volume streets. The problem can also become serious at driveways to high volume traffic generators such as shopping centers. The relationship between small single-radius curves and low operating speeds is not well defined in design manuals for various design vehicle types. Although knowledge of vehicle tracking has been well developed and applied to geometric design, its quantitative relationship to speed of operations is not readily available to the designer. There is a need to provide the designer with data and standards which relate curb return radii to such parameters as lane and exit throat widths, approach speeds, and traffic volumes. This should permit selection of curb radii with more precision than now occurs.

3. OBJECTIVE: The objective of the study are (1) to synthesize available data and/or analyze and relate field-determined operating speed of turns to radius, approach lane width, existing throat width, approach speed, and traffic volumes for various vehicle design types; (2) to develop design parameters useful for selecting intersection curb return radii; and (3) to disseminate findings in a brief designer's notebook publication as well as in a documental research report.

4. KEY WORDS: Driveway; curb return radius.

5. RELATED WORK:

   a. "Technical Guidelines for the Control of Direct Access to Arterial Highways" Glennon, J. C. et al., Midwest Research Institute, Report Nos. FHWA-76-86 and -87, Federal Highway Administration, August 1975.

   b. "Evaluation of Factors Influencing Driveway Accidents," McGuirk, W. W., District of Columbia Department of Transportation; Satterly, G. T., Jr. Purdue University: 1976.

   c. "Evaluation of Driveway-Related Accidents in Texas" (Abridgment) Rogness, R.O., Texas Transportation Institute; 1981.

   d. "Analysis of Exiting Vehicle Paths at Undivided Two-Way Driveways, (Abridgment) Richards, S. H.: Texas Transportation Institute, 1981.

   e. "Operational Effects of Driveway Width and Curb Return," Richards, S. H., Texas Transportation Institute; 1981.

6. URGENCY/PRIORITY: Data on driveway and curb radius design does not currently exist in a brief guideline form. Development of such guidelines should receive priority because the number of locations to which the guidelines would be applicable is so large.

7. COST: $65,000

8. USER COMMUNITY: The user community will be municipalities and agencies dealing with access problems of new or older developments as they relate to vehicular operations entering or leaving arterial streets. The results should be of particular use to planning professionals or planning officials not conversant with traffic operations and geometrics.

9. IMPLEMENTATION: A designer-oriented guide which will lead to improved operations through better design of intersecting streets and driveways is needed.

10. EFFECTIVENESS: Improved intersection operation will result from more deliberate selection of radii that are consistent with needs.

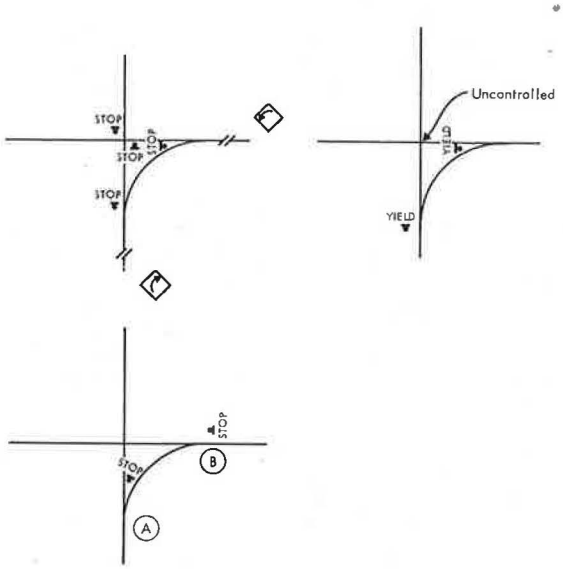
Problem No. 6

1. TITLE: Geometric Design and Operational Problems Associated with Turning Roadways at Rural Intersections.

2. PROBLEM: It is common practice to use one or more turning roadways at rural intersections. In some cases these turning roadways are equivalent to right-turn-only lanes which seldom cause design or operational problems. However, in many cases these turning roadways carry two-way traffic and, often, the predominant flow. There is a definite lack of consistency in the design and signing at these locations.

   The Manual on Uniform Traffic Control Devices does not address this problem. Some local agencies have designed the following warning signs to handle this traffic control situation:

The present generation of traffic engineers has inherited many of these types of rural intersections. They are confusing to the unfamiliar driver at best. Most highway agencies have a tendency to oversign this type of intersection. Some of the typical signing schemes found today are shown below:




The problem is actually a multiple intersection signing problem which can be improved through geometric changes. However, current geometrics often make it impossible to clearly assign the right of way to crossing flows of traffic (for example, at points A and B in the previous figure).

Another related problem is that many of these turning roadways do not have enough superelevation. The combination of the lack of consistency of signing and poor geometrics often results in these locations having high accident rates.

3. OBJECTIVE: The general objective of this research should be the determination of the proper way to sign and/or reconstruct rural intersections with one or more of these turning roadways.

The specific objectives are as follows:

a. Develop warrants for the construction of turning roadways as defined in this problem statement.

b. Develop warrants for reconstruction to eliminate turning roadways.

c. Develop a uniform signing policy for use if reconstruction is not possible.

   (1) Warning signs (2) Use of stop and/or yield signs

d. Develop specific pavement marking and/or delineation policies.

   (1) Use of chevrons
   (2) Use of delineators
   (3) Use of edge markings if roads are paved

4. KEY WORDS: Rural intersections; signing; geometrics; and turning roadways.

5. RELATED WORK: Some work is being done under a contract between the Kansas Department of Transportation, Kansas State University, and the University of Kansas. However, these researchers could not find any other pertinent data on this research topic.

6. URGENCY/PRIORITY: With the abundance of these types of intersections on our rural road system and the current environment toward the liability of local governmental agencies, it is extremely urgent that a policy be developed on how to design and operate this type of rural intersection.

7. COST: $50,000

8. USER COMMUNITY: The results of this research will be a definite benefit to the many township and county highway personnel who are responsible for the design and operation of rural roads. Since these types of locations are also found on rural state highways, it is also anticipated that most of the state highway agencies would also benefit from this information.

9. IMPLEMENTATION: The research findings could be used to standardize the signing procedures at these locations.

10. EFFECTIVENESS: Without a doubt, results from this research would make our rural roads a safer network for the general public.

Problem No. 7

1. TITLE: Roadway Design for Pickups and Vans

2. STATEMENT OF PROBLEM: Many elements of roadway design are predicated on the characteristics of the vehicles which will use the facility. Depending on the application, the design vehicle is typically either a car or large truck with design or operating features with extreme values of a critical characteristic. Because light trucks do not appear to have unusual design features, they are rarely selected as the design vehicle. Yet,

accident data indicate that these vehicles should be considered in roadway design.

Although data are difficult to obtain, information on motor vehicle production suggests that pickup trucks account for 15-16% of motor vehicles in the U.S. Limited data also indicate that these vehicles account for approximately this same percentage of vehicle-miles of travel. Fatal Accident Reporting System (FARS) data show that pickups/ vans are involved in 17% of all fatal accidents. However, there is evidence that these vehicles are involved in 25% of all fatal overturning crashes. In addition, data from predominately rural states supports the finding that these vehicles are dramatically overrepresented in overturning crashes.

3. OBJECTIVE: Because pickups and vans are overrepresented in overturning crashes, this study will

   a. Determine which specific characteristics of these vehicles contribute to their propensity for overturning. In addition to some obvious physical features, which need to be quantified, there may also be characteristics of the type of driver or vehicle use which accentuate the problem.

   b. Evaluate existing roadway and roadside design standards to determine if and how they should be modified to accommodate the special characteristics of these vehicles. Consideration will be given to detailed accident site studies, field testing and/or computer modeling of vehicle performance.

4. KEY WORDS: Highway design; pickups; light trucks; vans; and roadside design.

5. RELATED WORK: The technical literature reports very little on the specific topic of this proposed research. A 1977 Bibliography on Rollover Accidents identifies articles dealing with related topics, including injury causation in these crashes, the effect of restraint systems, and models for predicting vehicle dynamics. Numerous articles discuss rollovers of tractors/trailers, while others examine the problem with respect to compact and recreational vehicles. A 1982 NHTSA report examined the problem of fatal rollover crashes involving utility vehicles. Attention has also been devoted to the rollover potential of certain barrier terminals.

   A recent study noted the high involvement of these vehicles in rollover crashes. The emphasis in this study was the roadway characteristics and it found that overturning crashes are more likely to occur at locations with adverse roadway geometrics.

6. URGENCY/PRIORITY: The problem is quite real, and it is likely to become more serious if the popularity of these vehicle types continues to increase. There is no reason to believe that the problem will become less serious if it is ignored.

7. COST/TIME: It is suggested that $150,000 over an 18-month period would be required to properly address the problem.

8. USER COMMUNITY: The principal users of the findings of this research will be responsible highway designers. It is anticipated that the major applications will be related to rural highway alignment, safe roadside slopes, and possibly fixed objects. Relevant study findings may also be useful to the manufacturers of these vehicles.

9. IMPLEMENTATION: As long as light trucks are manufactured in accord with applicable motor vehicle standards, and are operated on facilities designed to accommodate small cars and large trucks, their operators will reasonably assume that the roadways are suitable for their vehicles. The accident data suggest, however, that this may not be the case, and that there may be a need to modify some design standards to account for the characteristics of pickups and vans in the same manner that the characteristics of other vehicles are recognized in the design process.

10. EFFECTIVENESS: The findings of this study should be highly effective, because a roadway/ roadside which is safe for these vehicles should be even safer for other vehicle types. The implementation for new construction could be easily accommodated. The application of remedial action to existing facilities will obviously involve a longer-term program. However, current work on establishing priorities for improvement of potential rollover crash sites should assist in selecting locations for the adoption of procedures recommended by this project.