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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, has been engaged in an activity which its membership believes is one of its major charges, that of identifying research needs and communicating them to the transportation research community. The committee has previously evaluated and published research problem statements, and the publication of this circular is a continuation of that activity.

EVALUATION METHOD

In previous evaluations of research problem statements, the committee has found that a single evaluation of research problem statements by its membership did not produce clear-cut priority rankings regardless of the evaluation criteria used, e.g., perceived importance or allocation of a hypothetical research budget. However, the committee's experience has shown that, although individual members ranked research problem statements differently, there was unanimity among the respondents as to which problems were of the highest and lowest priorities.

In this instance, the individual committee members were instructed to evaluate each of six current research problem statements for perceived importance, for allocation of a hypothetical research budget, and for probability of success, and to briefly provide the rationale for each evaluation. Twenty committee members responded to this request. The results were summarized in such a manner that anonymity of the respondents was maintained, and the summary was distributed to the entire committee. This summary was discussed and an ad hoc evaluation was conducted at the committee's 1980 mid-year meeting in Cherry Hill, New Jersey.

EVALUATION RESULTS

Of the 13 committee members in attendance at Cherry Hill, 10 had been respondents in the previous evaluation. The result of this face-to-face discussion was the clarification of some questions about several of the problem statements. At the conclusion of the meeting, four of the statements had been identified as having the highest priority. These statements are presented below. Two of the statements were judged to be of low priority and, as a result, are not included in this publication.

RESEARCH PROBLEM STATEMENTS

Problem No. 1

Name of Problem

Paved Shoulders at Low-Volume Rural Intersections

Problem

The practice of paving shoulders on low-volume rural roads to permit through and right-turning vehicles to bypass left-turning vehicles at intersections has become an increasingly important concept. Although implementation is not currently widespread, the states of Illinois, Kentucky, and Virginia presently permit this practice. In this current era of energy conservation and limited funds for capital improvements, the addition of paved shoulders at rural intersections has the potential for improving traffic service, reducing delays, conserving energy, and maximizing economic benefits.

The paved shoulder is considered a low-cost alternative to widening the pavement and constructing an exclusive left-turn lane. This approach is consistent with the 3R philosophy of providing acceptable levels of service and safety without large capital expenditures to achieve the full design standards that would be employed on higher-type facilities. Often, these rural intersections are not signalized, exist on relatively high-speed facilities and do not possess adjacent land uses where multiple driveways are prevalent. All of these characteristics suggest an effective reservoir area for left-turning vehicles and a bypass area for through and right-turning vehicles that can be accommodated within an expanded pavement area, approaching and departing the intersection. Frequently, this improvement can be implemented without the need for extensive engineering time and costs.

As with any new or modified operational practice, a careful evaluation is needed to assure that unanticipated operational, safety or legal problems do not occur. Furthermore, the need to establish appropriate design criteria for use by other agencies that become interested in the paved shoulder concept is important to ensure consistency of application.

Objectives

Research on the use of paved shoulders at low volume rural intersections should have the following objectives:

1. to evaluate the operational and safety performance of intersections with paved shoulders; and

2. to establish design criteria for such locations.

The operational and safety evaluation should include a comparison of the accident experience at intersections with and without paved shoulders. An operational evaluation should include field studies or analytical modeling to estimate the benefits due to reduction in delay and energy consumption. Construction costs of paved shoulders should be estimated. Current laws and rules of the road within each state should be investigated to determine if any legal conflicts exist in implementing this concept. If no legal or safety problems are apparent at intersections with paved shoulders, a simple benefit-cost comparison should be employed to determine whether the construction of paved shoulders is economically justified.

Design criteria for intersections with paved shoulders should be established. Specific areas that should be addressed are as follows:

Geometric criteria - pavement width, shoulder width and shoulder length;

Traffic control criteria - pavement markings and traffic signs;

Structural criteria - type and thickness of shoulder material;
and

Limitations and restrictions - high volumes, truck traffic and situations.

For this proposed study, it is recommended that the development of geometric and traffic control criteria be emphasized.

Key Words

Rural intersections, low-volume roads, paved shoulders, left-turn treatments.

Related Work

An HRIS search has found no studies that specifically address the issue of paved shoulders as an alternative to an exclusive left-turn lane. The research should be coordinated with current studies including "Development of Warrants for Special Turning Lanes at Rural Non-Signalized Intersections" being conducted by the University of Nebraska-Lincoln, "The Development of Criteria for the Treatment of Right-Turn Movements on Rural Roads" being conducted by the Virginia Highway Research Council, and "Geometric Treatments for Reducing Passing Accidents at Rural Intersections on Two-Lane Highways," being conducted for the Federal Highway Administration.

Urgency/Priority

This research problem should be given relatively high priority because of the current emphasis on energy conservation and continued decreases in the level of capital expenditures available for roadway improvements. Further, a recent study of population trends indicates the fastest growing areas in some parts of the United States are the small cities, towns, and rural communities beyond the suburban fringe.

Cost

$70,000.

Implementation

The results of this research will be of use to governmental agencies who are searching for low-cost design alternatives to improve both safety and operations on low-volume roads.

Problem No. 2

Name of Problem

Design Speed and Horizontal Curve Design.

Problem

A critical design problem arises as to what constitutes acceptable horizontal curve design practice on lower design speed (90 kph) highways when a relatively sharp curve follows an extended tangent section where operating speed is not strongly correlated with design speed. Motorists tend to overdrive lower design speed highways partly because the safe side friction levels are overly conservative to the average driver. Existing nationwide horizontal curve design policies are based to a great extent on the concept of design speed which seems insufficient based on observed driver behavior.

Objectives

The research should undertake an extensive field evaluation of operating speed to determine more accurate correlations of apparent design speed with roadside topography, highway classification and roadway geometric features. Also, data would be collected to determine "practical side friction factors" at horizontal curves following extended tangent sections. Based on these results, maximum horizontal curvature rates and recommended design practice for the design of a series of curves following extended tangent sections on different classes of highways will be established.

Key Words

Highways, rural roads, horizontal curve design, driver expectancy, design speed.

Related Work

The Federal Highway Administration (FHWA) recently signed a contract with Jack E. Leisch and Associates, to study the "Effectiveness of Design Criteria for Geometric Elements." As part of that research project, the following geometric elements are being studied to determine their influence on highway safety: degree of horizontal curve, type of curve transition, rate of superelevation, design speed and length of superelevation runoff. This project is on-going and it could have some useful answers relative to this particular research topic.

Babkov (1) discusses relationships between safety and geometrics. The safety of traffic can be appraised by the ratio between the speed of vehicles allowed on a dangerous section and the speed at the end of the previous section (V_{en}). Investigations of a great number of roads established that sections with a safety factor, K_s, with $K_s = V/V_{en}$, of 0.8 to 1.0 are safe for the running of the fastest single vehicles." The following tabulation is typical of data contained in this publication:

Dependence of Accident Rate on Radius and Number of Horizontal Curves

Radius of curve, m	Number of Curves per kilometer	Accident Rate per Million Vehicle-Km.
	0.3	1.6
<580	0.6 - 1.0	1.87
	2.5 - 3.0	1.50
	0.3	3.06
580 - 290	0.6 - 1.0	2.62
	2.5 - 3.0	1.60
	0.3	8.20
<175	0.6 - 1.0	3.70
	2.5 - 3.0	2.20

In 1969, John Glennon (2) conducted a state-of-the-art study concerned with the validity of horizontal curve standards. A comprehensive review of the AASHO standards was conducted, along with a review of reports, studies and procedures used by different states. The major conclusions of this review were:

1. The standard centripetal force equation used for curve design is valid only if the curve radius is large (curves of four degrees or less) and appears to yield low values of friction demand when the degree of curvature exceeds 20°.

2. The assumption that vehicles follow the design path of a highway curve does not account for the correction maneuvers necessary when drivers deviate from this path. These corrective maneuvers may require a larger coefficient of friction to maintain the vehicles' course.

3. It appears that friction factors on many roadways are lower than the design value, which would decrease stopping and cornering ability.

Urgency/Priority

Recent research has found the practical operating speed to be greater than the design speed for low design speed (< 90 kph) roadways. To avoid potential operational and safety problems, improved horizontal curvature design practice is needed. Also with the current emphasis on 3R-type projects, which could result in higher operating speeds without improved geometrics, this research topic is extremely urgent and should receive a top priority.

Cost

$200,000 over a 2-year period.

Implementation

The results of this research should provide information on when, how, and if to sign for horizontal curves and when, how, and if to implement 3R improvements. The user community would be state and county highway agencies. If the research results were published through AASHTO or an FHWA circular, they would have an excellent chance of being implemented. The user community is very responsive to findings published by these two organizations.

References

1. Babkov, V. F. Road Conditions and Traffic Safety. Translated from Russian, MIR Publishers, Moscow, 1975. 358 pages.

2. Glennon, J. C. "State-of-the-art Related to Safety Criteria for Highway Curve Design." Texas Transportation Institute, College Station, Texas, 1969.

Problem No. 3

Name of Problem

Geometric Design Controls and Criteria for Crest Vertical Curves.

Problem

The trend in recent years toward lower vehicles has resulted in a gradual reduction of the height of the driver's eyes above the surface of the roadway and a consequent restriction of sight distance in many situations. The current design criteria for driver eye height used in computing stopping sight distance is 3.75 feet. Recent studies have shown that the 15th percentile eye height is about 3.5 feet. Operating speeds on relatively flat crest vertical curves may be greater than the design speed on rural highways. These two factors each indicate that current design practice may result in unsafe crest vertical curves. The two factors in combination compound the safety problem.

Objectives

There are five research objectives:

1. to collect and analyze accident data to quantify the accident problem at crest vertical curves;

2. to expand the data base on driver eye height and project future driver eye heights;

3. to collect and analyze data on vehicle operating speeds for various classes of crest vertical curves for determining the relationship between driver eye height and operating speeds;

4. to develop and prioritize remedial countermeasures for identified operational problems on vertical curves;

5. to recommend required changes in current vertical curve design practice based upon identified existing problems.

In addressing objectives 4 and 5, appropriate consideration must be given to both stopping and passing sight distance and to horizontal curvature in conjunction with vertical curvature.

Key Words

Vertical alignment, vertical curve, driver eye height, sight distance, stopping sight distance, passing sight distance.

Related Work

The University of Michigan (1) has examined accident records from the Ohio and Pennsylvania Turnpikes to determine the influence of grade on accidents. Dart and Mann (2) also examined accident records for a 5-year time period (1962-1966) on approximately 1,000 miles of rural highway to find the relationship for several geometric features to accidents. Little relationship was found between vertical alignment and accidents. However, Chapter 12 of the current document on "Traffic Control & Roadway Elements - Their Relationship to Highway Safety" (3) points out that increased accident rates for reduced sight distances in transitional crest sections have been demonstrated. C. Lee (4) has made a study of some 2,000 large-format photographs showing drivers and vehicles operating at normal road speeds and under ordinary driving conditions for the purpose of determining information on eye height which could be used for design purposes. He presents material to show the magnitude of the downward trend in heights, to provide a measure of the range in dimensions resulting from many variables in vehicular and driver characteristics, and to establish a basis for the selection of representative design quantities. Another study (5) has determined that the 15th percentile driver eye height for passenger cars is 3.5 feet. This compares to 3.75 feet used in current highway design practice. The results show that driver eye heights for 89 percent of the compact and smaller passenger cars and 73 percent of the intermediate and full size passenger cars are less than 3.75 feet.

Lefeve (6) has collected and analyzed free-moving passenger car speeds on vertical curves where the minimum sight distance was between 150 and 500 feet. His analysis showed a reduction in average speed as drivers approach vertical curves. He also provides a relationship between operating speeds at the crest of vertical curves and the minimum sight distance and the relationship of driver performance on vertical curves, in terms of operating speeds, to the safe speed as determined by various design standards. The effect of vertical curvature on headlamp visibility is also examined in Highway Research Board Proceedings 17 (7).

To meet the third objective of this proposed research, researchers should be aware that the Swedish Road Research Institute (8) has developed equipment which can rapidly determine a roadway's vertical curvature.

Both procedures and remedial measures have been developed to resolve operational problems associated with vertical curves. Nomograms for rapid determination of minimum curve lengths that provide maximum visibility in terms of braking distances and passing maneuvers have been developed in Italy (9), as have clothoide curves (10) intended to best match the psycho-physical qualities of man and the technical characteristics of the vehicle. Researchers in Australia (11) have developed a vehicle trajectory model that they use to compute the steer angle history necessary for a vehicle to precisely follow a given vertical and horizontal road alignment. M. Livneh et al., (12) have theoretically determined, and presented in graphical form, the zone of passing visibility for crest vertical curves. Finally, the Texas Transportation Institute (TTI) (13) has evaluated safety warning systems for alerting motorists approaching crest vertical curves on urban freeways of the presence of stoppage waves downstream from the crest.

Recommended changes in current vertical curve design practices have been discussed by several researchers. Glennon (14) has proposed a new philosophy that considers the visual requirements for safety that are dependent upon operational conditions. D. Woods (15) of TTI provides examples which illustrate the need for a design concept which provides drivers with visual contact with the roadway surface that is greater than is currently being provided. He provides a new conceptual format for vertical alignment in the form of tables on minimum response distances for unexpected situations.

L. Louis (16), of Australia, also concludes that a different approach is warranted for assessing the minimum sight distance and passing requirements for crest vertical curves. Lastly, Pushkarev (17) introduces the need to relate highway alignment to the visual field; e.g., the ratios of roadbed and sky in the cone of vision.

Research on a topic related to this problem statement is currently underway at the University of Michigan Highway Safety Research Institute in NCHRP Project 15-8, "Parameters Affecting Stopping Sight Distance and Vehicle Acceleration/Deceleration Characteristics." This research will evaluate several important parameters affecting stopping sight distance on crest vertical curves including: (1) perception and reaction time; (2) driver eye height; (3) height of an object in the roadway; and (4) braking distance as affected by tire performance, brake system performance, pavement skid resistance and grades. This ongoing study represents one important element of crest vertical curve research, but the research recommended in this problem statement is broader in scope and emphasizes the use of accident data to identify and quantify safety problems at crest vertical curves and the identification and evaluation of remedial countermeasures for crests on existing highways.

Urgency/Priority

The proposed research is important because of new vehicle design characteristics which have produced lower driver eye heights. At the same time, braking distances have changed because new types of brakes and tires are now being used. Also, there is a trend towards use of larger trucks. Vertical curve design is a long-neglected problem which has been the basis for many tort suits and is the bane of the operating engineer on roads with older designs. It is important that this research begin soon because of the safety implications and because the collection of the required data will take considerable effort.

Cost

$250,000.

Implementation

The results of this research will be of use to both those who design highways and those in charge of highway oprations. The research findings can be used to change the criteria for crest vertical design and to provide countermeasures at existing unsafe crest vertical curves. Implementation of the research findings should increase safety of vehicle operations at crest vertical curves.

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7. Noble, C., et al. Thoughts on Highway Design Research as Related to Safety of Vehicle Operation. Highway Research Board Proceedings 37, Vol. 17, Part 1.

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10. Biffignandi, G. The Problems of Highway Traffic - Road Geometry. Permanent International Association of Road Congresses, Milan, Italy, 1976.

11. Good, M. Evaluation of Transition Curve Design Parameters Using an Analytical Vehicle Model. Australian Road Research Board, Victoria, Australia, 1977.

12. Livneh, M., et al. Visibility Problems in Crest Vertical Curves. Highway Research Record 70.

13. Dudek, C., and Biggs, R. Design of a Safety Warning System for the Gulf Freeway. Texas Transportation Institute Report 165-4, 1972.

14. Glennon, J. A Safety Evaluation of Current Design Criteria for Stopping Sight Distance. Highway Research Record 312, 1970.

15. Woods, D. Vertical Alignment Effects on Safe Vehicle Operation. Texas Transportation Researcher, 1970.

16. Louis, L. Sight Distance Requirements of Rural Roads - A Review. Australian Road Research Board, Victoria, Australia, 1977.
17. Pushkarev, B. Esthetic Criteria in Freeway Design. Highway Research Board Proceedings 62, Vol. 41.

Problem No. 4

Name of Problem

Moderation of Street Design Standards.

Problem

The construction of freeways in future years is anticipated to be considerably reduced. With this prospect in mind, and the continuing shrinking of available highway revenues, highway administrators are more than ever faced with the necessity of reducing standard requirements to more realistically fit available funds and needs. The provision of the necessary arterial elements of street systems seems to be severely hampered by the stringency of modern design standards, projects tend to be large and extremely expensive, street improvements are continually falling behind needs.

Objectives

It is proposed that this project be directed towards the reexamination of present design standards and development of possible modifications which would result in more affordable designs which are adequate functionally and safe, acceptable to the public and can be maintained more economically. The research should recognize that private automobiles may continue to become smaller in size, decreased in power, and will travel at relatively slower speeds; that there will be increased control of truck movements; and that arterials will possibly be required to accommodate greater numbers and types of transit vehicles.

Key Words

Design standards, cross sections, pavement, shoulder width, median width, cost, functional, safe.

Related Work

The Highway Research Information Service, Washington, D.C. has provided a collection of abstracts through a computerized literature search entitled, "Vehicle Size Related to Street Design Standards" and "Street Design." There were eighteen articles identified in the search. Two of these are strongly related to the problem statement. These are: (a) a synopsis by Loutzenheiser on geometric design, which discusses operational effects of different median treatments, including major streets through business areas; and (b) a book by the Urban Land Institute, which provides a guide to how we should arrive at better future practices in the design of different types of streets including major arterials.

Urgency/Priority

The research should be limited to a relatively short period of time. Recommendations are urgently needed now. Construction projects which would be affected by this research but which are unduly delayed could eventually be much more costly. The project should, therefore, be accorded high priority.

Cost

$100,000 over a period of one year.

Implementation

Application of results from this research should produce street geometry more acceptable to communities and compatible with future vehicular designs and available funds. Effective transfer of research results to local, state and federal standards and policies could result in accelerated implementation of study findings.