Preliminary Report on Landscape Design Factors and Their Influence on Highway Safety

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The problem of safety on the highway affects most everyone directly or indirectly in everday life. Since the automobile arrived on the scene, motor vehicle traffic accidents have increased to the extent that today they rank among the leading causes of death in this country. A review of available information shows that significant improvement in traffic safety has been made in recent years.

Congress recognized the increasing seriousness of the problem in the development of the program for the National System of Interstate and Defense Highways. The Federal-Aid Highway Act of 1956 authorized and directed the Secretary of Commerce to investigate and study what action could be taken by the Federal Government to promote the public welfare by increasing highway safety.

The findings and recommendations of this study are contained in a 1959 report (A1). This report recognizes the magnitude and complexity of the highway safety problem and the need for an improved approach in its solution. The report indicates that progress will require: (a) improved knowledge of the basic causes of accidents, (b) a well-planned schedule of basic and applied research, and (c) the attraction of qualified representatives of the many interests concerned to participate in a coordinated highway safety plan. Consideration of landscape design factors will contribute important aspects to such a coordinated highway safety plan.

Chapter III of the 1959 Report, under that portion dealing with the highway element, states that "a highway, to offer a maximum of safety, must be designed within practical limits to satisfy the existing and future patterns of human behavior and vehicle development.... To satisfy the needs and desires of the drivers while operating their vehicles and at the same time to provide safety, many features must be properly incorporated into the highway. Principal ones include alinement, profile, clearances, horizontal dimensions of the highway cross-section, interchanges, traffic controls, and many other details which comprise the functional geometry of highway design and operation."

Although considerable knowledge has been obtained and large sums spent on vehicle development and highway research the real gap in present knowledge is in the understanding of human factors. Preliminary results from a study of the human factor, although difficult to measure, show promise of important findings that may be used in solving problems of highway safety.

In relation to human factors that underlie driving behavior there are two particular problems that occur due to driving conditions. They are vigilance and fatigue. It is not unusual for some people on occasion after a busy day of work or other activity, to drive long distances at night, forcing themselves to overcome lack of sleep. In driving over long distances the loss of vigilance, and the depletion of energy or fatigue may become important factors in driving errors.

The present concern is in the field of design and physical characteristics of the highway, particularly the beneficial influence that landscape design factors can contribute toward improved highway safety.

The purpose of this report is to bring together a resumé of information: what we know concerning landscape design factors, to discuss ways in which some of these factors have improved safe movement of traffic on the highway, and to suggest and recommend those landscape design factors in which further research is needed. A thorough search for, and review of, published material on this subject should be made before undertaking specific research projects.

LANDSCAPE DESIGN FACTORS AND HIGHWAY SAFETY

Some of the important landscape design factors and their influence on highway safety are: (a) conservation of landscape features in highway location, (b) cross-section design and right-of-way width, (c) planting design, (d) development of special areas (that is, safety rest areas and interchanges).

The first consideration should be the conservation of landscape features in highway location as an aid to safety. In the planning of modern highways the use of long easy curvature or "spline alinement," designed to permit safe vehicle operation at higher speeds, has also been used to reduce land disturbance and damage to desirable existing landscape features. These existing features may be preserved to aid in controlling erosion, to improve highway safety by reducing headlight glare, aid in guiding traffic movements and to serve as a crash barrier.

Monotony, usually associated with lack of alertness and driver fatigue may have a definite bearing on

traffic accidents. Where natural features exist and the requirements of roadway alinement permit their proper preservation, such features improve the environment of the roadway for highway users by adding variety and interest within and along the roadside area. Long straight sections of highways may contribute to driver hypnosis which is associated with monotony and fatigue. Monotonous highways are dangerous because they contribute to drowsiness, or at least laxness, on the part of many drivers traveling at continued high speed. For example, Table 14 (D1) shows that 60 percent of all casualties occurred on the "straightaway," not in turning, slowing, or backing. The importance of driver fatigue as a contributor to highway accidents has been recognized by the following five agencies: (a) Army Transportation Corps, (b) Army Medical Research Laboratory, (c) Public Health Service, (d) Interstate Commerce Commission, and (e) Civil Service Commission. As indicated on page 109 (A1) these five agencies are now conducting or planning studies on the contribution of driver fatigue to traffic accidents.

In the design of modern highways, the profile grade line should be adjusted in relation to alinement to conserve important landscape features and at the same time provide adequate vertical sight distance in keeping with traffic requirements. Awkward combinations of alinement and profile which may adversely affect driver behavior should be avoided where possible. The preservation of features, where they do not interfere with design controls, may screen from the view of drivers combinations of alinement and profile grade that may create deceptive or misleading traffic movements. Research is needed on the conservation of landscape features as a means of improving the highway environment to aid in safe traffic movement.

Most highway engineers are convinced of the advantages of the modern "safety cross-section design" where topography and other conditions permit use of flatter earth slopes. The design for high-speed highways which provide transitional refinements in alinement and profile for safe traffic movement should also provide similar transtional refinements in the shaping of the well-rounded cross-section where traffic and economic conditions justify. Flattened and rounded slopes not only reduce the cost of erosion control and tend to protect the highway investment, but also increase the chances of the motorists who must in an emergency leave the roadway to regain control of his car.

K. A. Stonex (B1) stressed the safety benefits of flat well-rounded side slopes and wide, gently rounded drainageways. The author presents reasonable evidence that where topography and economic conditions permit, liberally-rounded slopes and drainageways, preferably 6:1 and flatter, will aid in roadside safety. Such slopes can be used in flat topography without additional cost where construction operations are planned adequately. However, in rolling topography, the use of such flat slopes in safety cross-section design will undoubtedly require increased right-of-way widths, and some additional grading and protection against erosion, which will result in increased costs. The extent to which such costs may be justified as a means of improving highway safety as well as roadside maintenance operations is a subject for economic research.

In areas of the country subject to heavy snowfall, the streamlined self-cleaning cross-section with side slopes 5:1 or flatter is becoming more widely accepted as a method of reducing maintenance, and improving the safe movement of traffic during winter months. Where conditions permit, the typical roadway section is elevated above the adjacent land, and constructed with broad, well-rounded drainageways and flattened slopes which permit the wind to blow the snow across and off the roadway.

The use of guardrails as safety measures on many sections of roadway has been questioned by an increasing number of highway engineers. There is general agreement that guardrails should be eliminated wherever possible.

The fact that the unit cost of moving earth has remained relatively stable over the past 25 yr may justify the use of flatter slopes as a basis for eliminating guardrails. There is some expressed opinion that earth fills graded with 4:1, or flatter, slopes may be warranted up to about 15 ft in depth. Some states provide standard plans for a non-guardrail cross-section with 4:1 slopes on fills up to 10 ft in depth. The extent to which fill sections may be flattened and rounded, and the appropriate slope ratio and rounding to use based on topographic, economic and approved safety controls is a subject on which additional research data are needed. The optimum depth of fill and slope ratio as opposed to guardrail installation, including maintenance costs, would be useful information in furthering the adoption by the states of improved standards for cross-section design and right-of-way width.

Another subject for research is a detailed cost accounting of test projects over a planned period of years in which acquisition and maintenance costs of a wide right-of-way, with flat well-rounded slopes of the safety-cross-section type, would be compared with an older type of cross-section on a narrow right-of-way with steep slopes and little or no rounding.

Research information is needed to determine the optimum cross-section design commensurate with highway capacity, cost of right-of-way, construction costs, and provisions for future expansion, including an evaluation of safety benefits. Stonex (B1) has shown a comprehensive cost comparison between three highway cross-section design standards for 1926, 1940 and 1960. This is a good example of desirable research data.

Drainage is one of the most important problems of highway construction and is a basic consideration in the design of the cross-section. Inadequate drainage and pavement failures affect the efficiency and safety of moving traffic. Streams frequently cross under the roadway and, due to changing land use, embankments often are subject to destructive flooding. Changes in stream channels should be avoided wherever possible.

On rural highway areas the preservation of strips of existing natural growth along streams, particularly where highway embankments parallel streams or shorelines, will provide necessary protection to the highway structure and to highway users.

Erosion control on roadsides has not only proved itself from an economic standpoint, but also has proved to be a beneficial factor in highway safety. The protection of the roadside area from erosion is vitally important in case motorists have to use these border areas in an emergency. If, due to unusual circumstances, a vehicle does leave the traffic lane out of control, eroded or rough side slopes may have a direct bearing on the severity of an accident.

The introduction of the median strip, or separation of one-way roadways on divided highways, is generally recognized by highway engineers as one of the most important contributions to highway safety. Research data by Keese and Pinnell (B2) indicate that "different type and width medians had some effect on traffic behavior. The wider medians are valuable in reducing or eliminating the effect of opposing flow and high volumes on traffic behavior."

Wide medians are generally desirable, but in urban areas are usually limited to widths of from 4 to 20 ft because of high cost of right-of-way. In many urban areas, narrow medians are provided with guardrail or some type of barrier intended to prevent head-on collisions.

In rural areas where land costs are lower, wider rights-of-way are usually acquired, thus permitting variable width medians and, in rolling topography, different roadway levels in which desirable native growth can often be saved. The use of widely separated roadways is also an advanatage in reducing headlight glare, and eliminating head-on collisions.

Research is needed to determine the optimum width of median which should be provided, based on land costs and other factors, including safety benefits, derived from existing growth which can be saved in the median to control erosion and to reduce or eliminate headlight glare, as well as reduced maintenance cost of mowing grass.

To provide a complete and safe traffic facility a careful analysis of the entire right-of-way is necessary, particularly of the outer roadside or border area. As a general rule, on major rural sections of highways, it is in this outer roadside border that the greatest possibilities exist for conserving natural landscape features when widths of at least 50 ft are provided beyond the outer edges of roadway shoulders. Increased widths of border areas are often desirable to permit (a) conservation of unusual landscape features, (b) safety cross-section grading, (c) improved drainage, (d) adequate erosion control, and (e) functional planting.

The retention of existing growth within the highway right-of-way and the proper use of plant material can protect the public investment and aid in the safe and efficient flow of traffic. The Garden State Parkway in New Jersey and the Baltimore Washington Parkway in Maryland are two excellent examples of highway construction that illustrate this point. Modern highway landscape design, particularly that portion dealing with planting design, is based on the concept of providing and using plant growth for useful purposes. Before planting plans are prepared, each project is analyzed in the initial design stage to determine (a) the purpose for which planting may be needed, and (b) the controls governing the feasibility of planting and their influence on planting design. No planting is done which will interfere with safe sight distance commensurate with the design speed of the highway.

For major highways a minimum planting clearance of 25 ft from the edge of pavement of through traffic lanes is necessary for shade trees planted in roadside borders and median areas. It is obvious, of course, that the design of all tree and shrub planting must conform with future highway expansion requirements. Published information is available regarding the use of plant material on highways for specific purposes such as planting to screen headlight glare, aid traffic guidance, serve as a crash barrier, control snow drifting, and control noise, dust and fumes.

The use of widely separated one-way roadways is the best known method of controlling or reducing headlight glare. In many cases existing native growth has been saved in the median to block out opposing headlights. At critical sections of divided highways where headlights create serious conditions, planting may be introduced to overcome a hazardous situation. Planting in narrow medians (4 to 12 ft) frequently used in urban areas may prove unsatisfactory inasmuch as favorable growth of plants is difficult to achieve in narrow medians under certain city conditions. Research is needed to find plant material that will withstand adverse conditions in cold climates, where snow storage frequently occurs in medians and calcium chloride is used for ice removal. In reports to this committee, Deakin has presented a number of excellent articles on the use of plant material for headlight glare screening (C2b; C4c, d, f).

Research is needed to determine design criteria with respect to the extent to which additional median width could be acquired in lieu of providing a screen (including original cost and maintenance) as a means of reducing glare.

The planting of trees and shrubs to aid in guiding traffic may be used in the following situations where conditions are favorable:

1. On the outside of curves to indicate turning movements at intersections and interchanges;
2. Beyond the junction of two lanes of traffic to serve as a background for moving vehicles;
3. To accentuate the approach to a structure, or to transitional widths of pavements; and
4. To screen out distracting traffic movements in a complex interchange.

An important aspect of modern highway design is the speed at which drivers operate vehicles under variable roadway and traffic conditions. This speed factor has brought about a need for focusing the driver's attention on one thing at a time, especially when encountering complex sections of highway where time for making decisions is limited.

Research information is needed on the proper use of plant material to emphasize the time-distance factor as a warning and guide for high-speed traffic.

In 1954 a program for testing the effectiveness of multiflora rose plantings as crash barriers was approved and sponsored by the University of New Hampshire and the Bureau of Public Roads. An article by Skelton (A2) indicates that limited safety benefits to motorists can be realized by the use of crash barrier plantings. Some states have undertaken experimental plantings of this type. Research regarding additional safety benefits to motorists in the use of crash barrier plantings is needed.

In cold climates where drifting snow creates serious problems to traffic movement, the installation of living snow fences for control of snowdrifting has provided some improvement to driver safety. One northern state reports more than 600 mi of "natural" snowfence has been planted and attained sufficient growth to fulfill its purpose. Limited information is available on this subject. More data would be helpful.

Planting for the abatement of highway noise, dust and fumes has received much attention in the past 10 yrs and considerable information is available. HRB Bulletin 110 (C4i) outlines current information on noise abatement, and suggests types of problems on which further research is needed. The use of plants as a means of reducing the carbon monoxide content given off by an increasing number of automobiles, trucks and buses offers possibilities for research. At least one state has taken steps to reduce air pollution by requiring a special device on autos to control exhaust fumes.

Included in the category of Special Areas are safety rest areas and interchanges. Motorists have been encouraged to stop and rest so as to overcome driver fatigue or highway tension. The design of rest areas with adequate traffic and comfort and convenience facilities for emergency stops and rest periods has been accepted as a means of improving highway safety. There is need for improving knowledge of human factors, and considerations of driver behavior, in the design of highways.

There is some expressed opinion that motorists on controlled-access highways are reluctant to leave the expressway at interchanges for a rest stop. Motorists must leave Interstate highways at interchanges for vehicle service, also for food and overnight stopping, inasmuch as Federal legislation does not permit these services to be provided within the right-of-way. To plan more adequately for safety rest areas on primary and Interstate highways, considerable research data are needed. The Bureau of Public Roads in November 1959 requested such information from the states through its regional and division offices. The limited data received indicate that additional research is needed.

It has been said that from a psychological approach the mind and body can function better in a pleasant and enjoyable environment. There is some expression that sound landscape design will add interest to motoring, increase the attention of drivers, and relieve the strain of high-speed travel.

Interchanges are often complex areas due to the very nature of traffic design requirements. It seems reasonable to assume that anything that can be done to reduce complexity would improve driver behavior and traffic safety.

Functional planting may be advantageous to: (a) reduce glare and confusion of opposing traffic movements on ramps and adjoining frontage roads; (b) guide the turning movement of traffic on ramps; and (c) reduce the detrimental or confusing effects of adjacent commercial, residential, industrial or other distracting developments.

CONCLUSION

Three important points brought out in the Federal Report on Highway Safety are the need for: (a) improved knowledge of the basic causes of accidents; (b) a comprehensive well-planned schedule of basic and applied research; and (c) qualified representatives of the many interests concerned to participate in a coordinated highway safety plan.

Committee action is suggested to determine (a) profitable short- and long-range research objectives, (b) a specific order and priority of selected subjects, and (c) an outline or method of development to carry out the research objectives.

Additional knowledge on understanding human factors as they relate to driver behavior is needed. The fact that more people are spending longer hours on improved highway demands more attention and effort on the part of highway engineers to improve the driving environment. Inasmuch as the drivers are subject to, and influenced by, the environment of roadsides, whether confused or well-ordered, it seems reasonable that better designed, attractive, efficiently maintained highways will contribute to highway safety.

Published information indicates some progress regarding the beneficial influence of landscape design factors on the safe movement of traffic. Highway Research Board publications prepared by this committee and material compiled by public and private organizations are available as a source for research study.

A selected list of publications is included in this preliminary report dealing with landscape design and highway safety which should be helpful in establishing a program for specific research. The benefits of research generally are seldom questioned but the subject matter, method of approach, amount of money

available, and similar problems may be controversial. Research in all fields for the benefit of highway safety, including the field of landscape design, is worthy of concerted effort.

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