Design Speed, Operating Speed, and Posted Speed Practices
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Design Speed, Operating Speed, and Posted Speed Practices

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Subject Areas
Highway and Facility Design

Research Sponsored by the American Association of State Highway and Transportation Officials
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Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board’s recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an assurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

Note: The Transportation Research Board of the National Academies, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers’ names appear herein solely because they are considered essential to the object of this report.
THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy’s purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The Transportation Research Board is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board’s mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board’s varied activities annually engage more than 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. www.TRB.org

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Kay Fitzpatrick, Research Engineer, Texas Transportation Institute, was the Principal Investigator. The other authors of this report, also of TTI, are Paul Carlson, Associate Research Engineer; Marcus A. Brewer, Associate Transportation Researcher; Mark D. Wooldridge, Associate Research Engineer; and Shaw-Pin Miaou, Research Scientist. The work was performed under the general supervision of Dr. Fitzpatrick.

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This report examines the relationship between design speed and operating speed through a survey of the practice and a thorough analysis of geometric, traffic, and speed conditions. The basis for recent changes in speed definitions in AASHTO’s *A Policy on Geometric Design of Highways and Streets* (Green Book) and the *Manual on Uniform Traffic Control Devices* (MUTCD) are presented. Researchers should find the data (available on the accompanying CD-ROM) to be very useful in further exploring relationships between roadway factors and operating speed. The report will be of interest to designers and others interested in understanding the factors that affect drivers’ speeds.

Speed is a fundamental concept in transportation engineering. The Green Book, MUTCD, and other references use various aspects of speed (e.g., design speed, operating speed, running speed, 85th percentile speed) depending on the application, but the definitions of these aspects have not always been consistent between documents. These inconsistencies resulted in ambiguous and sometimes conflicting policies.

Design speed is a critical input to the Green Book’s design process for many geometric elements. For some of these elements, however, the relationship between the design speed and the actual operating speed of the roadway is weak or changes with the magnitude of the design speed. Setting a design speed can be challenging, particularly in a public forum, and alternative approaches to design may be beneficial and should be explored.

Under NCHRP Project 15-18, the Texas Transportation Institute compiled and analyzed industry definitions for speed-related terms and recommended more consistent definitions for AASHTO’s Green Book and the MUTCD. The researchers surveyed state and local practices for establishing design speeds and speed limits and synthesized information on the relationships between speed, geometric design elements, and highway operations. Next, researchers critically reviewed geometric design elements to determine if they should be based on speed and identified alternative design-element-selection criteria. Geometric, traffic, and speed data were collected at numerous sites around the United States and analyzed to identify relationships between the various factors and speeds on urban and suburban sections away from signals, stop signs, and horizontal curves (all elements previously found to affect operating speeds).

In addition to including the survey of practice and information on the relationships between speed and various geometric and traffic factors, this report suggests refinements to the Green Book in the following areas: design speed definitions; information on posted speed and its relationship with operating speed and design speed; how design speed values are selected in the United States (noting that anticipated posted speed and anticipated operating speed are also used in addition to the process currently in the
Green Book, which is based on terrain, functional class, and rural versus urban); changes to functional class material; and additional discussion on speed prediction and feedback loops. The included CD-ROM contains the field data that should be combined with future data collection efforts to gain a better understanding of the factors that influence operating speed in urban and suburban areas.
Speed is used both as a design criterion to promote consistency and as a performance measure to evaluate highway and street designs. Geometric design practitioners and researchers are, however, increasingly recognizing that the current design process does not ensure consistent roadway alignment or driver behavior along these alignments. The goals of the NCHRP 15-18 research project were to reevaluate current procedures, especially how speed is used as a control in existing policy and guidelines, and then to develop recommended changes to the design process. Objectives completed included the following:

- Review current practices to determine how speed is used as a control and how speed-related terms are defined. Also identify known relationships between design speed, operating speed, and posted speed limit.
- Identify alternatives to the design process and recommend the most promising alternatives for additional study.
- Collect data needed to develop the recommended procedure(s).
- Develop a set of recommended design guidelines and/or modifications for the AASHTO A Policy on Geometric Design of Highways and Streets (commonly known as the Green Book).

Strong relationships between design speed, operating speed, and posted speed limit would be desirable, and these relationships could be used to design and build roads that would produce the speed desired for a facility. While the relationship between operating speed and posted speed limit can be defined, the relationship of design speed with either operating speed or posted speed cannot be defined with the same level of confidence. The strongest statistical relationship found in NCHRP Project 15-18 was between operating speed and posted speed limit for roadway tangents. Several variables other than the posted speed limit do show some sign of influence on the 85th percentile free-flow operating speed on tangents. These variables include access density, median type, parking along the street, and pedestrian activity level.

Previous studies have found roadway variables that are related to operating speed, including access density and deflection angle (suburban highways); horizontal curvature...
and grade (rural two-lane highways); lane width, degree of curve, and hazard rating (low-speed urban streets); deflection angle and grade (rural two-lane highways); and roadside development and median presence (suburban highways).

A strong limitation with all speed relationships is the amount of variability in operating speed that exists for a given design speed, for a given posted speed, or for a given set of roadway characteristics.

Design speed has a minimal impact on operating speeds unless a tight horizontal radius or a low K-value is present. On suburban horizontal curves, drivers operate at speeds in excess of the inferred design speed on curves designed for 43.5 mph (70 km/h) or less, while on rural two-lane roadways, drivers operate above the inferred design speed on curves designed for 55.9 mph (90 km/h) or less. When posted speed exceeds design speed, liability concerns arise even though drivers can safely exceed the design speed. While there is concern surrounding this issue, the number of tort cases directly involving that particular scenario was found to be small among those interviewed in a Texas Department of Transportation (TxDOT) study.

The safety review demonstrated that there are known relationships between safety and design features and that the selection of the design feature varies based on the operating speed of the facility. Therefore, the design elements investigated within this study should be selected with some consideration of the anticipated operating speed of the facility. In some cases the consideration would take the form of selecting a design element value within a range that has minimal influence on operating speed or that would not adversely affect safety. In other cases the selection of a design element value would be directly related to the anticipated operating speed.

Factors used to select design speed are functional classification, rural versus urban, and terrain (used by AASHTO); AASHTO Green Book procedure, legal speed limit, legal speed limit plus a value (e.g., 5 or 10 mph [8.1 to 16.1 km/h]), anticipated volume, anticipated operating speed, development, costs, and consistency (state DOTs); and anticipated operating speed and feedback loop (international practices).

Functional classification is used by the majority of the states, with legal speed limit being used by almost one-half of the states responding to the mailout survey conducted during NCHRP Project 15-18. A concern with the use of legal speed limit is that it does not reflect a large proportion of the drivers. Only between 23 and 64 percent of drivers operate at or below the posted speed limit on non-freeway facilities. The legal speed limit plus 10 mph (16.1 km/h) included at least 86 percent of suburban/urban drivers on non-freeway facilities with speed limits of 25 to 55 mph (40.2 to 88.5 km/h) and included at least 96 percent of rural drivers on non-freeway facilities with speed limits of 50 to 70 mph (80.5 to 112.7 km/h).

While the profession has a goal to set posted speed limits near the 85th percentile speed (and surveys say that 85th percentile speed is used to set speed limits), in reality, most sites are set at less than the measured 85th percentile speed. Data from 128 speed study zone surveys found that about one-half of the sites had between a 4- and 8-mph (6.4- and 12.9-km/h) difference from the measured 85th percentile speed. At only 10 percent of the sites did the recommended posted speed limit reflect a rounding up to the nearest 5-mph (8.1-km/h) increment (as stated in the Manual on Uniform Traffic Control Devices [MUTCD]). At approximately one-third of the sites, the posted speed limit was rounded to the nearest 5-mph (8.1-km/h) increment. For the remaining two-thirds of the sites, the recommended posted speed limit was more than 3.6 mph (5.8 km/h) below the 85th percentile speed.

The classification of roadways into different operational systems, functional classes, or geometric types is necessary for communication among engineers, administrators, and the general public. In an attempt to better align design criteria with a roadway clas-
sification scheme, a roadway design class was created in NCHRP Project 15-18. To recognize some of the similarities between the classes for the new roadway design class scheme and the traditional functional classification scheme, similar titles were used. The classification of freeway and local street characteristics was straightforward. Determining the groupings for roads between those limits was not as straightforward. The goal of the field studies was to identify the characteristics that, as a group, would produce a distinct speed. For example, what are the characteristics that would result in a high speed and high mobility performance as opposed to those characteristics that would result in a lower speed. The results of the field studies demonstrated that the influences on speed are complex. Even when features that are clearly associated with a local street design are present (e.g., no pavement markings, on-street parking, two lanes, etc.), 85th percentile speeds still ranged between 26 and 42 mph for the 13 sites. Such wide ranges of speeds are also present for other groupings of characteristics. Because of the variability in speeds observed in the field for the different roadway classes and the large distribution in existing roadway characteristics, the splits between different roadway design classes need to be determined using a combination of engineering judgment and policy decisions.