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A Research Program for Improvement of the *Highway Capacity Manual*

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Transportation Research Board
500 Fifth Street, NW
Washington, D.C. 20001
www.TRB.org

Ann Petty, Production Editor; Pam Caswell, Proofreader; Jennifer J. Weeks, Layout

Preface

The year 2000 edition of the *Highway Capacity Manual* (HCM), commonly known as the HCM2000, represented a major step forward in highway capacity analysis capabilities. However, there are still improvements to be made in the HCM, and its present scope does not fully address all facility types of potential interest to HCM users. This document sets forth a research program for improvement of the HCM. It is the product of extensive deliberations by the members of the TRB Highway Capacity and Quality of Service Committee (HCQS) and of feedback from users of the HCM.

The program recommends the conduct of 38 research studies as a means to permit improvements to the present HCM and upgrade future editions to meet user needs. The estimated total cost of the program is $16.0 million over the next 10 years. This estimated cost includes direct research expenses, the development of draft chapters, and the production of a major revision of the HCM.

Contents

Introduction

BACKGROUND—IMPORTANCE OF THE HCM

The *Highway Capacity Manual* (known throughout the world as the HCM) is a key document in the field of traffic operations. The HCM presents analytical procedures and supporting information needed to assess the capacity and quality of service of highway facilities. Such analyses form an important part of the justification for nearly every major highway improvement project. Billions of dollars in highway improvements are based, in part, on HCM analyses.

The development of the HCM is guided by the TRB committee on HCQS, a volunteer committee including representatives of public agencies, engineering consultants, and researchers. The HCQS Committee assures that the HCM contains the best available procedures for traffic operational analysis and encourages research to develop better procedures that represent the state of the art of traffic operational analysis.

Originally published in 1950, the HCM was the first document to quantify the concept of capacity for transportation facilities. A major update of the HCM in 1965 introduced the level-of-service concept, which has become the foundation for determining the adequacy of transportation facilities from the perspectives of planning, design, and operations. The 1985 edition of the HCM, along with its 1994 and 1997 updates, advanced traffic operational analysis capabilities still further. The latest HCM edition, published in the year 2000, is known as the HCM2000.

DEVELOPMENT OF THE HCM2000

The HCM2000 represents a major advance in the state of the art and the state of practice concerning the assessment of highway capacity and quality of service. The HCM2000 was planned in *TRB Circular 371: A Program of Research in Highway Capacity*, published in June 1991. Research based on that plan was pursued over a period of 9 years, leading to the publication of the HCM2000. The research that led to the HCM was funded in large part by the National Cooperative Highway Research Program, which is jointly sponsored by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO), as well as directly by FHWA and individual highway agencies.

The major features of the HCM2000 that represent advances over previous HCM editions include

- Publication in both printed and multimedia CD formats;
- Publication of editions in both metric and US customary units;
- Revised and expanded introductory material on proper use of HCM procedures and the interpretation of HCM results;

- Reorganization of material to present analysis concepts separately from the operational analysis procedures that apply those concepts;
- New or revised analytical procedures for virtually every facility type addressed by the HCM;
- A new part of the HCM dealing with corridor and areawide analyses, which were not addressed previously; and
- A new part of the HCM dealing with simulation and other models, which were not addressed previously.

The HCM is TRB's largest selling publication; more than 13,200 copies of the HCM2000 have been sold in the 3-year period since its release.

USER NEEDS FOR THE NEXT EDITION OF THE HCM

Since the publication of the HCM2000, the HCQS Committee has undertaken an effort to obtain input from users on their experiences in using the HCM. The committee received comments gathered in a series of approximately 10 focus groups, each with 10 to 12 HCM users as participants, during 2002 and 2003. These focus groups were held in diverse geographical areas, and the participants included planners, design engineers, operations engineers, and educators.

In addition to the focus groups, an audit of the HCM was conducted by members of the HCQS Committee. This audit was conducted in the areas of planning applications, design and operations, and planning.

The overall results of the focus groups and the audit indicate that the HCM2000 is widely used and accepted and provides useful tools for capacity analysis of transportation systems. The results also indicate that the HCM could be improved to provide greater accuracy and to analyze situations that are not addressed by the current methodologies. The following discussion summarizes the major suggestions for improvement of the HCM, including comments from HCM users in the focus groups and the results of the audit of the HCM by planners, design and operations engineers, and educators. A full report on user feedback on the HCM2000 is available on the HCQS Committee website.

HCM Focus Group Comments

On the basis of the results of the focus groups, it is seen that HCM users had the following general comments concerning potential improvements to future editions of the HCM:

- Roadway networks and the impacts of traffic at adjacent intersections are not well addressed.
- The additional detail provided in many areas of the HCM2000 is useful.
- Comments on the new format introduced in the HCM2000 were mixed, although there was a preference for including all discussion of a particular methodology within one section, rather than placing certain introductory material in separate concepts chapters.
- The planning applications are not widely used because the operations methods are easy to apply.

- Adding complexity to the HCM is seen as desirable, as long as it leads to more accurate results.
- More field data verification is desired.
- More guidance in selecting default values is desired.
- Some participants would like to see confidence intervals calculated.
- Many participants expressed a desire to retain the level of service concept.
- Additional analysis of level of service F (LOS F) conditions is desired, particularly the ability to distinguish between gradations of LOS F.
- Part I of the HCM (Overview) is useful. Part IV (Corridor and Areawide Analyses) is too generic to be useful, and network models are easier to apply.
- Part V (Simulation and Other Models) is useful but would be more useful if it had comparisons of specific models.

HCM Audit of Planning Applications

The audit of the HCM conducted by the HCQS Committee indicated the following needs for the improvement of planning applications in the HCM:

- There are currently many gaps in the HCM where the needed default values are not specified.
- Some procedures have imbedded input parameters that show up only in certain types of analyses. For example, in certain signalized intersection problems, the user is sometimes required to specify the percentage of traffic on a shared lane. In the case of certain unsignalized two-way, stop-controlled (TWSC) intersection problems, a user who selects two-stage gap acceptance needs to specify the queue storage area. In order to create an ideal model for planning applications, it would be necessary to seek out these imbedded parameters and determine default values or make a determination that the user must supply them.
- The signalized intersection methodology represents a special challenge because it requires the selection of a cycle length and phase times. From an operational applications point of view, these are critical input variables that have an important impact on the operation of the traffic signal. However, from a planning applications point of view, the cycle length and phase times are details that are not known and difficult to estimate. In planning applications, the analyst will usually prefer to assume that a reasonable timing plan is in place. However, if an algorithm is used to select the cycle length and phase times, additional complications develop. There is the question of whether it is appropriate to have very poor levels of service for some movements in order to minimize overall intersection delay. Another issue is the level of rounding for cycle lengths. Many traffic engineers (but not all) would prefer to round cycle lengths to the nearest 5 or 10 s.
- There are some cases, such as analysis of unsignalized TWSC intersections, where the operational methodology does not produce estimates of levels of service for the entire facility, section, segment, or control point.
- In most cases, the HCM methodologies are not able to accurately produce travel time and/or delay estimates for conditions where hourly demand exceeds hourly capacity.

The assessment of the HCQS Committee, based on user feedback and the committee's own observations, is that the HCM2000 offers important advantages for planning applications, as compared with previous versions. However, improvements could still be made. The Planning Applications Subcommittee of the HCQS Committee has defined a list of ideal characteristics of planning procedures that have not yet been fully incorporated into the HCM methodologies. The HCM could be improved for planning applications by incorporating these ideal characteristics and giving the user more flexibility in incorporating default values into the HCM methodologies.

HCM Audit of Design and Operations Applications

HCM users and HCQS Committee members confirmed the overall usefulness of the HCM for design and operational analyses. However, the audit of the HCM for design and operations indicated the following situations in which the HCM could be improved:

- The HCM is a static tool that cannot adequately account for system and time impacts (e.g., queue building).
- LOS F conditions are oversimplified. Generally, the HCM can predict when LOS F will or will not occur, but cannot give any guidance as to the severity of delays and queues at this level of service.
- In intersections analyses, the HCM procedures are focused on isolated intersections. The effect of queued traffic spilling into adjacent intersections is not adequately addressed.
- Analysis of a lane is not associated with the length of the lane.
- Work zones are not adequately addressed.
- The HCM lacks a definitive procedure for roundabouts.
- There are only limited procedures for the analysis of systems of roadways and intersections.
- While the HCM provides an answer for many problems, there is no indication of the variability of the answer or confidence interval.
- Certain specialized conditions are difficult to analyze. These include U-turns at intersections, traffic operations at toll plazas, traffic operations in high occupancy vehicle (HOV) lanes, transit signal priority, and ramp metering.

The assessment of the HCQS Committee is that, in the areas of design and operational analysis, the HCM2000 is a widely accepted tool that provides useful methodologies for the analysis of roadway traffic, pedestrians, bicycles, and transit. However, there are specific situations, identified above, where the HCM methodologies do not provide guidance on a particular capacity analysis problem or where the accuracy of the HCM methodology is questionable. Continued efforts to improve the HCM design and operations methodologies are highly recommended.

HCM Audit from the Point of View of Educators

The HCM was not developed with educators in mind. However, as its popularity has become more universal, the HCM is being used increasingly as an educational tool. Educators and their students can now be considered as one of the audiences that the HCM is attempting to serve. The following issues were identified in the HCM audit regarding educational applications of the HCM:

- The HCM explains its methodologies in terms that are readily understood by users who already have some basic knowledge. More needs to be done to provide the novice reader with a better understanding of the procedures and terminology. There are a number of good textbooks that do this, but the HCM itself does not.
- The explanation of the HCM analysis procedures is uneven, and important material is scattered throughout the text. The HCM describes what to do but does not always explain why that should be done.
- The HCM presents only one approach to each type of analysis. This is understandable because the presentation of alternative approaches could be confusing to HCM users. Some critique of the HCM methodologies is provided by the sections that discuss their limitations. However, for the benefit of those interested, some source should present and discuss alternatives to the HCM methodologies.
- The HCM provides worked examples developed using the manual HCM worksheets. It would also be useful to present worked examples developed using computer routines or to direct users to sources where such worked examples are available.
- The worked examples should be presented in linear (step-by-step) fashion rather than in spreadsheet fashion; spreadsheets make it difficult for readers to follow the sequence in which computation are made.
- The HCM to explain more fully the field measurement techniques for obtaining HCM measures.

In summary, it is recognized that the HCM was not intended to be a textbook for students, but a manual for practitioners with a certain level of knowledge. However, there is a great need to provide educational material related to the HCM methodologies. Both incoming students and researchers developing future capacity procedures would benefit from better documentation of why the HCM procedures were selected over alternative procedures. While this type of discussion may not be appropriate for inclusion in the manual itself, it would be desirable to provide such information, either by incorporation into the HCM text or in separate documents that could be made available to the intended audience.

HCM STRATEGIC PLAN

The HCQS Committee is developing a strategic plan for the future improvement of the HCM. At the heart of this plan are 11 themes for future improvement of the HCM that were developed from a combination of HCM user feedback and HCQS Committee deliberation. These themes are identified in Table 1. The research program presented in Chapter 2 of this document includes research necessary to implement these 11 themes in improving the HCM. Each theme is briefly discussed below:

1. Existing HCM methodologies should be kept up to date and improved as needed. The HCM presents extensive analytical procedures that primarily address the quality of service for specific types of point locations and segments. The procedures should be continuously reviewed and updated to meet the needs of HCM users. Where specific improvement needs are identified, they should be addressed in research and revised analytical procedures should be incorporated in the HCM.

TABLE 1 Summary of Themes for Future HCM Improvement

1	Existing HCM methodologies should be kept up to date and improved as needed.
2	The HCM should deal more comprehensively with assessment of the quality of service for facilities and systems made up of point locations and segments.
3	The HCM should take a broader multimodal perspective and should have expanded capabilities to assess the quality of service provided to different types of travelers using the same point, segment, facility, or system.
4	The HCM should deal more quantitatively with the assessment of quality of service for oversaturated conditions.
5	The HCM should provide better assurance to HCM users that its quality of service measures are consistent with traveler perceptions of quality of service.
6	HCM methodologies should be validated so that users can be assured of the reasonableness of the results.
7	The HCM should include methodologies for assessment of the quality of service for point, segment, and facility types that are not currently addressed in the HCM.
8	Applications guides should be prepared for a broad range of HCM applications.
9	The HCM should provide more guidance on the application of traffic simulation models in conjunction with HCM procedures.
10	The HCM should provide procedures to quantify the likely variability in travel times due to recurring and nonrecurring congestion and to help highway agencies use those results in communicating information on the reliability of travel times to travelers.
11	The HCM should provide measures that assist highway agencies in project prioritization and decision making.

2. The HCM should deal more comprehensively with assessment of the quality of service for facilities and systems made up of point locations and segments. The HCM originally addressed quality of service only for point locations, such as intersections, and segments, such as roadways between intersections. The chapter on urban arterials in the 1985 HCM was the first attempt to assess quality of service for a facility composed of a series of adjacent signalized intersections and intervening roadway segments. This arterials methodology, now renamed the urban streets methodology, is still not comprehensive because it does not consider the operational effects of unsignalized intersections and driveways on the roadway segments between signals. The HCM2000 introduced a freeway facilities chapter that combines the assessment of quality of service for a series of adjacent basic freeway segments, ramps, ramp junctions, and weaving areas and accounts for spillback effects resulting from the oversaturation of individual points or segments. The HCM2000 also took an important step toward assessment of systems larger than points, segments, and facilities with the introduction of HCM Part IV (Corridor and Areawide Analyses). While this was an important step forward, HCM users have found that the current version of HCM Part IV is too generic to be useful. The HCQS Committee recommends that

- The scope of HCM methodologies that address facilities composed of a series of points and segments should be expanded. In particular, the freeway facilities procedure should be expanded to become a comprehensive uninterrupted flow facilities procedure by adding the capability to include multilane highway and two-way highway segments in the analysis. The urban streets methodology should be revised to include the operational effects of unsignalized intersections and driveways between signalized intersections. Ultimately, the HCM should include both a comprehensive uninterrupted flow facilities methodology and a comprehensive interrupted flow facilities methodology.

- The HCM Part IV procedures for corridor and areawide analyses should be developed further and made more quantitative. HCM users should be provided more guidance concerning the use of results from network models in corridor and areawide analyses.

3. The HCM should take a broader multimodal perspective and should have expanded capabilities to assess the quality of service provided to different types of travelers using the same point, segment, facility, or system. Most HCM procedures address the quality of service for motor vehicle travel. Separate procedures are provided to assess quality of service for pedestrians, bicyclists, and transit users. These separate procedures for pedestrians, bicyclists, and transit users should be integrated into the point, segment, and facility chapters to which they apply, so that those chapters take a multimodal approach to assessing quality of service. It is anticipated that separate quality of service measures would be provided for each transportation mode, but that those measures would be derived from integrated procedures that reflect the interdependencies among the modes.

4. The HCM should deal more quantitatively with the assessment of quality of service for oversaturated conditions. The HCM is an effective tool for identifying where oversaturated conditions occur, but it is not an effective tool for quantifying traffic performance measures during oversaturated conditions. Analysis of oversaturated conditions requires consideration of multiple time periods and of queue spillback from the oversaturated points or segments to upstream points or segments. In the HCM2000, the freeway facilities procedure is the only procedure that explicitly addresses such issues. HCM users would like performance measures to quantify the user delays expected under oversaturated conditions and the delay reduction effectiveness of potential mitigation measures. Some users would like to have subdivisions of LOS F to indicate the degree of congestion resulting from oversaturation.

5. The HCM should provide better assurance to HCM users that its quality of service measures are consistent with traveler perceptions of quality of service. The primary function of the HCM is to serve as a decision-making tool for highway agencies to assess existing or anticipated traffic operational conditions and to assess the anticipated effects of proposed improvements. The HCM can best serve this function if the performance measures used to characterize the quality of service for points, segments, facilities, and systems are consistent with traveler perceptions of quality of service on those systems. The HCM should recognize that the appropriate quality of service measures may vary with the types of locations considered (points and segments) and the degree of aggregation of points and segments into facilities and systems. The service measures used in the HCM should be reviewed for consistency with traveler perceptions and, where appropriate, revised or replaced. However, any revised HCM methodology must not only realistically represent traveler perceptions of quality of service, but must do so in a way that preserves the usefulness of the HCM as a decision-making tool for highway agencies.

6. HCM methodologies should be validated so that users can be assured of the reasonableness of the results. Because HCM analyses serve as the basis for highway agency decisions concerning multimillion dollar investments, HCM users deserve assurance that the results of those analyses can be relied upon. Currently, there have been only limited efforts to validate HCM methodologies against field data or to formally assess the variance of results. Validation efforts should be undertaken and procedures provided in the HCM so that users can estimate confidence intervals for results. The confidence intervals for the results of HCM procedures should be consistent with the level of uncertainty in input data to HCM

methodologies. When concerns about the reasonableness of HCM results arise, existing HCM methodologies should be improved.

7. The HCM should include methodologies for assessment of the quality of service for point, segment, and facility types that are not currently addressed in the HCM. In addition, the capabilities of existing HCM methodologies should be expanded to include features not currently addressed. The HCQS Committee should undertake a systematic effort to identify point, segment, and facility types that are not addressed by the HCM, to identify geometric design and traffic control features that are not addressed in current HCM chapters, and to identify gaps between chapters that are not addressed. Where appropriate, new HCM methodologies should be developed, or existing methodologies modified, to address the identified needs. These new methodologies should be capable of assessing the quality of service for specific point, segment, and facility types under varying conditions. A new HCM methodology for signalized intersections and a new or modified methodology for freeway weaving areas are currently under development. Examples of additional new or modified methodologies that may be needed in future HCM editions include assessment of the quality of service for roundabouts, incidents and work zones, arterial weaving areas, toll facilities, and developed two-lane highways.

8. Applications guides should be prepared for a broad range of HCM applications. The National Cooperative Highway Research Program (NCHRP) Project 3-64 has developed a guide that illustrates the application of HCM procedures to several selected application types. The HCQS Committee plans to consider the need to provide guidance to users by illustrating a broader range of HCM applications. For example, a guide for planning and preliminary engineering applications of the HCM appears desirable. The need for other supplementary documents that help HCM users should be investigated.

9. The HCM should provide more guidance on the application of traffic simulation models in conjunction with HCM procedures. HCM Part V (Simulation and Other Models) has been developed specifically to assist users in deciding when and how to apply computer simulation models of traffic operations in conjunction with HCM procedures. Users have responded favorably to HCM Part V, but have indicated that they would like more detail and, in particular, comparisons between specific models. As a matter of TRB policy, the HCQS Committee has been reluctant to assess or compare specific simulation models, many of which are commercial products. However, the HCQS Committee should provide as much additional information as possible about the application of simulation models, without comparing specific models, and should encourage outside organizations to make any comparative results available to HCM users.

10. The HCM should provide procedures to quantify the likely variability in travel times due to recurring and nonrecurring congestion and to help highway agencies use those results in communicating information on the reliability of travel times to travelers. HCM methodologies currently provide deterministic estimates of performance measures and, thus, quality of service. In fact, performance measures are likely to vary from time period to time period, and from day to day, even under nominally similar conditions of recurring congestion. Furthermore, quality of service is frequently degraded by nonrecurring events such as traffic accidents whose specific occurrences cannot be forecast, but whose probabilities can be estimated. The HCM should assist highway agencies in estimating the variability and reliability of travel time estimates so that information can be used effectively in system management.

11. The HCM should provide measures that assist highway agencies in project prioritization and decision making. A primary application of the HCM by highway agencies is to

assess the effect of proposed improvement projects on quality of service. However, the HCM does not address how HCM results should be used in project prioritization and decision making and does not consistently provide measures that are needed by highway agencies for this purpose. For example, highway agencies might wish to use HCM results to rank proposed projects by delay reduction (expressed in vehicle-hours or person-hours) or by delay reduction per dollar of construction cost. In decision making, highway agencies might choose to value delay reduction differently in different levels of service. The HCM should include a new section on project prioritization and decision making. All existing and future HCM methodologies should be reviewed and improved to assure that they provide the measures needed by highway agencies for project prioritization.

To help set priorities for future improvements to the HCM, members and friends of the HCQS Committee rated the relative priority of the 11 themes. Based on this assessment, the following five themes for future improvement of the HCM are considered to have the highest priority:

- Quantitative assessment of oversaturated conditions (Theme 4),
- Comprehensive assessment of facilities and systems (Theme 2),
- Improvement of existing HCM methodologies (Theme 1),
- Multimodal assessment of quality of service (Theme 3), and
- Assessment of new point, segment, and facility types (Theme 7).

However, there is clearly a range of viewpoints within the HCQS Committee because each of the 11 themes received the highest priority rating from at least one individual and the lowest priority rating from at least one individual.

The 11 themes have been considered in the development of the recommended research program presented in Chapter 2.

2

Research Plan

PROGRAM HIGHLIGHTS

This chapter presents a research program for development of the next edition of the HCM. The plan includes 12 research projects with a total funding of $5.3 million that are currently under way or about to begin. The plan also includes 38 potential projects, with a total estimated cost of $16.0 million, which have not been funded but which need to be conducted over the next 10 years to provide a thorough revision and updating of the HCM2000. A more complete description of this recommended research program is presented below.

RESEARCH SINCE THE HCM2000

A substantial amount of research that will be useful in improving the HCM has been completed since the publication of the HCM2000, is already under way, or will begin soon. This research forms the foundation for the research plan presented below, which will build upon that foundation.

Table 2 summarizes completed or ongoing research on topics relevant to the HCM. The table, which is organized by topic, identifies the title, sponsor, funding level, and duration for each research project. Collectively, the 12 projects shown in Table 2 have received $5.3 million in funding, and their results are expected to make a significant contribution to improving the HCM.

Table 3 illustrates how the 12 projects funded to date address the 11 themes for future HCM improvement presented in Chapter 1.

RESEARCH NEEDS

Research needs for the next edition of the HCM have been identified to complement the research already under way. Table 4 presents the additional research that will be needed to complete the next edition of the HCM. The table, which is organized by topic, identifies the title, funding level, and duration for each research project. The HCM research needs that are not yet funded, as shown in Table 3, include 38 projects with an estimated total cost of $16.0 million. The appendix presents a research problem statement for each identified research need.

Table 5 illustrates how the 38 identified research needs address the 11 themes for future HCM improvement presented in Chapter 1. Each identified research need addresses at least one of the themes for future HCM improvement and many of the projects address multiple themes. The 38 recommended projects, as a whole, address each of the 11 themes. In addition, one of the themes—variability and reliability of travel times—will be extensively addressed in the anticipated Future Strategic Highway Research Program (F-SHRP).

TABLE 2 Highway Capacity Research Funded Since the HCM2000

Project	Sponsor or Project Number	Funding Level ($K)	Anticipated Completion Date
Freeways and multilane highways			
Procedures for analysis of freeway weaving areas and ramp junctions	NCHRP Project 3-75	450	3/07
Freeway bottleneck identification, analysis, and removal	NCHRP Project 3-83	600	TBD[a]
HCM-wide crosscutting issues			
HCM applications guide	NCHRP Project 3-64	250	8/03
Interchanges			
Interchange ramp terminals	NCHRP Project 3-60	300	3/05
Pedestrians and bicycles			
Characteristics of emerging road trail users and their safety	FHWA	340	1/04
Evaluation of quality of service and operation of shared-use paths	FHWA	350	9/03
Intersection level of service for bicycle through movements	Florida Department of Transportation (FDOT)	150	8/02
Planning and preliminary engineering			
Regional and national default values for highway capacity calculations	NCHRP Project 3-82	400	TBD
Two-lane highways			
Improvement of two-lane highway methodology in the HCM	NCHRP Project 20-7(160)	35	9/03
Unsignalized intersections			
Applications of roundabouts in the United States	NCHRP Project 3-65	700	6/05
Urban streets			
Estimating and measuring urban street traffic speed and level of service	NCHRP Project 3-79	625	9/07
Multimodal arterial level of service	NCHRP Project 3-70	1,100	6/07
	Total	5,300	

NOTE: These data are current as of February 2005.
[a]TBD = to be determined.

TABLE 3 Relationships of Individual Funded Projects to HCM Improvement Themes

	Funded Projects	1. Improvement of Existing HCM Methodologies	2. Comprehensive Assessment of Facilities and Systems	3. Multimodal Assessment of Quality of Service	4. Quantitative Assessment of Oversaturated Conditions	5. Consistency with Traveler Perceptions of Quality of Service	6. Validation of HCM Methodologies	7. Assessment of New Point, Segment, and Facility Types	8. Additional Applications Guides	9. Application of Traffic Simulation Models	10. Quantify Variability and Reliability Travel Times	11. Application to Project Prioritization and Decision Making
		Themes										
A	Estimating and measuring urban street traffic speed and level of service (NCHRP Project 3-79)	●	●									
B	Multimodal arterial level of service (NCHRP Project 3-70)		●	●		●						
C	Procedures for analysis of freeway weaving areas and ramp junctions (NCHRP Project 3-75)	●										
D	Freeway bottleneck identification, analysis, and removal (NCHRP Project 3-83)		●		●							●
E	HCM applications guide (NCHRP Project 3-64)								●			
F	Interchange ramp terminals (NCHRP Project 3-60)							●				
G	Characteristics of emerging road trail users and their safety (FHWA)			●								
H	Evaluation of quality of service and operation of shared-use paths (FHWA)			●								
I	Intersection level of service for bicycle through movements (FDOT)			●								
J	Regional and national default values for highway capacity calculations (NCHRP Project 3-82)			●					●			
K	Improvement of two-lane highway methodology in the HCM [NCHRP Project 20-7(160)]	●										
L	Applications of roundabouts in the United States (NCHRP Project 3-65)							●				

TABLE 4 Highway Capacity Research Needs for the Next Edition of the HCM

Project Number	Project	Funding Level ($K)	Anticipated Duration (years)
	Freeways and multilane highways		
1	Enhancements to the current procedure for freeway facilities in the HCM2000	400	2.0
2	Inclusion of multimodal and HOV facilities in the HCM freeway facilities procedure	400	2.0
3	Oversaturated analysis of freeway traffic flow	350	2.0
4	Operational and capacity effects of incidents on freeway systems	300	3.0
5	Analytical and simulation procedures for modeling components of toll facilities and toll systems	500	3.0
	HCM-wide crosscutting issues		
6	Production of the updated HCM	1500	3.0
7	Development of a procedure for predicting traffic performance in work zones	600	2.0
8	Application of HCM procedures to systems and corridors using real-time data collection	400	2.5
9	Procedures for calibrating and estimating the reliability of HCM analysis methods	600	2.0
10	Development of guidelines for the use of simulation and other models in highway capacity analyses	400	3.0
11	Synthesis to determine the extent of HCM use in project prioritization and decision making	25	1.0
12	Applying multimodal level of service to areawide analysis	200	1.0
13	Multimodal intersection level of service	500	2.0
14	Moving America over the road—trucking's impact on highway capacity and level of service	300	2.0
15	Freight impact on highway capacity and level of service for urban conditions	500	2.5
	Interchanges		
16	Improvement of the HCM interchange ramp terminal procedure (follow-on to NCHRP Project 3-60)	500	2.5
	Pedestrians and bicycles		
17	Pedestrian and bicycle delay and level of service calibration	200	2.0
18	Quality of service for various users of shared-use paths	250	2.0
	Planning and preliminary engineering		
19	Guidelines for coordinating roadway facilities and development densities	300	2.0
20	Planning and preliminary engineering applications guide to the HCM	250	2.0
21	Planning and preliminary engineering applications for freeway facilities	175	2.0
22	Planning analysis of oversaturated conditions	200	1.0
	Signalized intersections		
23	Delay and queue model validation	350	2.0
24	Development of an enhanced analytical framework for signalized intersections	350	2.0
25	Left-turn model verification and validation	200	2.0
26	Saturation flow-rate model verification and validation	300	2.0

(*continued*)

TABLE 4 (*continued*) Highway Capacity Research Needs for the Next Edition of the HCM

Project Number	Project	Funding Level ($K)	Anticipated Duration (years)
	Two-lane highways		
27	Effects of operational treatments on two-lane highway traffic operations	800	4.0
28	Traffic operational analysis methods for additional two-lane highway types	600	4.0
	Uninterrupted flow facilities		
29	Capacity and quality of service analyses for generally uninterrupted flow facilities	400	2.0
	Unsignalized intersections		
30	Assessment of simulation tools for unsignalized intersections	600	2.5
31	Development of traveler-based level of service methodologies for unsignalized intersections	400	2.0
32	Effect of traffic demand on gap acceptance at two-way stop-controlled intersections	300	2.0
33	Enhancement and calibration of the two-way stop-controlled intersection capacity analysis procedure	700	2.5
34	Unsignalized movements at signalized intersections	400	2.5
	Urban streets		
35	Modeling procedure for congested arterial facilities	400	2.0
36	Operational and capacity effects of unsignalized access on urban streets	350	2.5
37	Level of service for arterial weaving segments	600	3.5
38	Capacity and quality of service analysis of urban local streets	400	2.5
	Total	16,000	

TABLE 5 Relationships of Highway Capacity Research Needs to HCM Improvement Themes

		Themes										
	Recommended Projects	1. Improvement of Existing HCM Methodologies	2. Comprehensive Assessment of Facilities and Systems	3. Multimodal Assessment of Quality of Service	4. Quantitative Assessment of Oversaturated Conditions	5. Consistency with Traveler Perceptions of Quality of Service	6. Validation of HCM Methodologies	7. Assessment of New Point, Segment, and Facility Types	8. Additional Applications Guides	9. Application of Traffic Simulation Models	10. Quantify Variability and Reliability Travel Times	11. Application to Project Prioritization and Decision Making
1	Enhancements to the current procedure for freeway facilities in the HCM2000	●	●		●	●					●	
2	Inclusion of multimodal and high-occupancy vehicle facilities in the HCM freeway facilities procedure	●	●	●				●				
3	Oversaturated analysis of freeway traffic flow	●	●		●	●						
4	Operational and capacity effects of incidents on freeway systems		●		●	●					●	
5	Analytical and simulation procedures for modeling components of toll facilities and toll systems		●			●		●			●	
6	Production of the updated HCM	●	●	●	●	●	●	●		●	●	●
7	Development of a procedure for predicting traffic performance in work zones		●		●	●		●			●	
8	Application of HCM procedures to systems and corridors using real-time data collection		●								●	
9	Procedures for calibrating and estimating the reliability of HCM analysis methods	●					●					
10	Development of guidelines for the use of simulation and other models in highway capacity analyses		●		●					●		
11	Synthesis to determine the extent of HCM use in project prioritization and decision making											●
12	Applying multimodal level of service to areawide analysis		●	●								
13	Multimodal intersection level of service		●	●								

(*continued*)

TABLE 5 (*continued*) **Relationships of Highway Capacity Research Needs to HCM Improvement Themes**

Recommended Projects		Themes: 1. Improvement of Existing HCM Methodologies	2. Comprehensive Assessment of Facilities and Systems	3. Multimodal Assessment of Quality of Service	4. Quantitative assessment of Oversaturated Conditions	5. Consistency with Traveler Perceptions of Quality of Service	6. Validation of HCM Methodologies	7. Assessment of New Point, Segment, and Facility Types	8. Additional Applications Guides	9. Application of Traffic Simulation Models	10. Quantify Variability and Reliability Travel Times	11. Application to Project Prioritization and Decision Making
14	Moving America over the road—trucking's impact on highway capacity and level of service	●		●								
15	Freight impact on highway capacity and level of service for urban conditions	●		●								
16	Improvement of the HCM interchange ramp terminal procedure	●										
17	Pedestrian and bicycle delay and level of service calibration	●		●		●						
18	Quality of service for various users of shared-use paths			●		●		●				
19	Guidelines on coordinating roadway facilities with development densities		●									
20	Planning and preliminary engineering applications guide to the HCM			●					●			●
21	Planning and preliminary engineering applications for freeway facilities								●			●
22	Planning analysis of oversaturated conditions	●	●		●	●			●			●
23	Delay and queue model validation	●										
24	Development of an enhanced analytical framework for signalized intersections	●			●							
25	Left-turn model verification and validation	●			●		●					
26	Saturation flow-rate model verification and validation	●										

TABLE 5 (*continued*) Relationships of Highway Capacity Research Needs to HCM Improvement Themes

		Themes										
	Recommended Projects	1. Improvement of Existing HCM Methodologies	2. Comprehensive Assessment of Facilities and Systems	3. Multimodal Assessment of Quality of Service	4. Quantitative Assessment of Oversaturated Conditions	5. Consistency with Traveler Perceptions of Quality of Service	6. Validation of HCM Methodologies	7. Assessment of New Point, Segment, and Facility Types	8. Additional Applications Guides	9. Application of Traffic Simulation Models	10. Quantify Variability and Reliability Travel Times	11. Application to Project Prioritization and Decision Making
27	Effects of operational treatments on two-lane highway traffic operations	●						●				
28	Traffic operational analysis methods for additional two-lane highway types					●		●				
29	Capacity and quality of service analyses for generally uninterrupted flow facilities		●					●				
30	Assessment of simulation tools for unsignalized intersections									●		
31	Development of traveler-based level of service methodologies for unsignalized intersections			●		●						
32	Effect of traffic demand on gap acceptance at two-way stop-controlled intersections	●										
33	Enhancement and calibration of the two-way stop-controlled intersection capacity analysis procedure	●						●				
34	Unsignalized movements at signalized intersections	●										
35	Modeling procedure for congested arterial facilities	●	●		●			●				
36	Operational and capacity effects of unsignalized access on urban streets	●	●					●				
37	Level of service for arterial weaving segments		●			●		●				
38	Capacity and quality of service analysis of urban local streets							●				

The 38 identified research needs have been rated by members and friends of the HCQS Committee to establish the committee's recommended priorities for the research program. Priorities for each potential research project were rated on a 1 to 5 scale, with a rating of 5 representing the highest priority and a rating of 1 representing the lowest priority. The priority ratings are presented in Table 4. The table shows the 38 recommended research projects ranked in descending priority order from highest to lowest. Table 4 reflects a broad diversity of opinion within the HCQS Committee about priorities for future research needs. Every identified research need was rated as low priority (1 or 2) by at least one individual and high priority (5) by at least one individual. This diversity of opinion is considered to be a strength of the HCQS Committee process, and the average ratings indicate clear preferences, if not consensus, on the priorities for future research.

The priority ratings do not necessarily represent the sequence in which the research should be conducted. For example, the highest priority project—production of the updated HCM (Project 6)—will be the last project performed because it will contain the results of all the other recommended projects. The next section shows the HCQS Committee's vision of how the 38 recommended research projects should be organized into a coherent research program leading to the next HCM edition.

RECOMMENDED RESEARCH PROGRAM

The 38 research projects presented in Table 4 have been organized into a research program, with a schedule based on consideration of both the logical sequencing of research projects, the priorities presented in Table 6, and input from other interested organizations. Figure 1 presents the planned time schedule for the needed research to be completed over a period of 10 years.

Figure 2 illustrates the overall funding for each topic area in the research program as a whole, including both current projects (from Table 2) and planned projects (from Table 3). Table 7 presents a summary of the needed research funding by topic area and by year.

TABLE 6 Priority Rating of Research Needs for Future HCM Improvement

Project No.	Topic Area	Problem Statement Title	Priority Ranking	Average Rating	Min. Rating	Max. Rating
6	HCM-wide crosscutting issues	Production of the updated HCM	1	4.3	1	5
7	HCM-wide crosscutting issues	Procedures for predicting traffic performance in work zones	2	4.1	2	5
3	Freeways and multilane highways	Oversaturated analysis of freeway traffic flow	3	3.9	1	5
35	Urban streets	Modeling procedure for congested arterial facilities	4	3.8	2	5
10	HCM-wide crosscutting issues	Development of guidelines for the use of simulation and other models in highway capacity analyses	5	3.7	1	5

(*continued*)

TABLE 6 (*continued*) **Priority Rating of Research Needs for Future HCM Improvement**

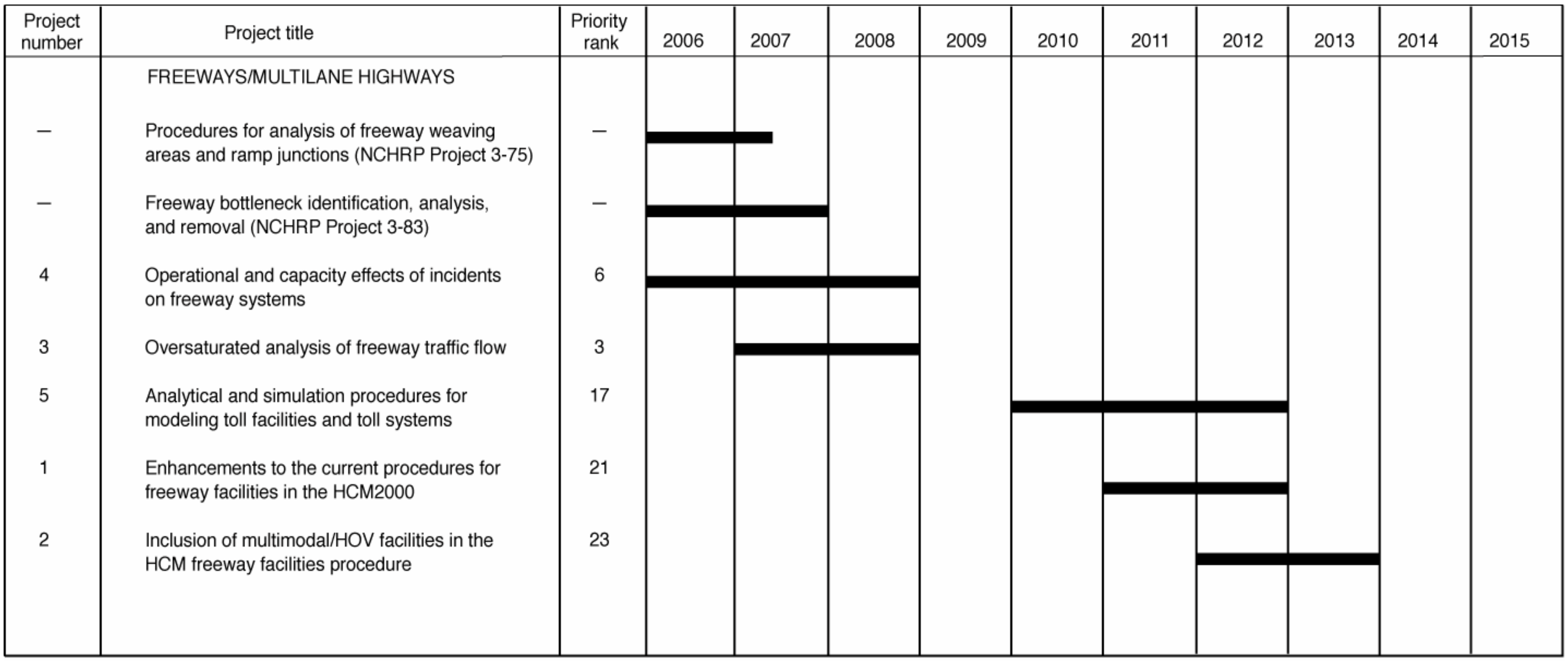
Project No.	Topic Area	Problem Statement Title	Priority Ranking	Average Rating	Min. Rating	Max. Rating
4	Freeways and multilane highways	Operational and capacity effects of incidents on freeway systems	6	3.6	1	5
28	Two-lane highways	Traffic operational analysis methods for additional two-lane highway types	6	3.6	1	5
29	Uninterrupted flow facilities	Capacity and quality of service analyses for generally uninterrupted flow facilities	6	3.6	2	5
20	Planning and preliminary engineering	Planning and preliminary engineering applications guide to the HCM	9	3.5	1	5
36	Urban streets	Operational and capacity effects of unsignalized access on urban streets	9	3.5	1	5
23	Signalized intersections	Delay and queue model validation	11	3.4	1	5
32	Unsignalized intersections	Effect of traffic demand on gap acceptance at two-way stop-controlled intersections	11	3.4	1	5
16	Interchanges	Improvement of the interchange ramp terminal procedure	13	3.3	1	5
24	Signalized intersections	Development of an enhanced analytical framework for signalized intersections	13	3.3	1	5
27	Two-lane highways	Effects of operational treatments on two-lane highway traffic operations	13	3.3	2	5
37	Urban streets	Weaving area level of service for arterial street segments	13	3.3	1	5
5	Freeways and multilane highways	Analytical and simulation procedures for modeling components of toll facilities and toll systems	17	3.2	1	5
9	HCM-wide crosscutting issues	Calibrating and estimating reliability of HCM analysis methods	17	3.2	1	5
13	HCM-wide crosscutting issues	Multimodal intersection level of service	17	3.2	1	5
33	Unsignalized intersections	Enhancement and calibration of the two-way stop-controlled intersection capacity analysis procedure	17	3.2	1	5
1	Freeways and multilane highways	Enhancements to the current procedure for freeway facilities in the HCM2000	21	3.1	1	5
25	Signalized intersections	Left-turn model verification and validation	21	3.1	1	5
2	Freeways and multilane highways	Inclusion of multimodal and high occupancy vehicle facilities in the HCM freeway facilities procedure	23	3.0	1	5
8	HCM-wide crosscutting issues	Application of HCM to systems/corridors based on real-time data collection	23	3.0	1	5

(*continued*)

TABLE 6 (*continued*) **Priority Rating of Research Needs for Future HCM Improvement**

Project No.	Topic Area	Problem Statement Title	Priority Ranking	Average Rating	Min. Rating	Max. Rating
23	Planning and preliminary engineering	Planning and preliminary engineering applications for freeway facilities	23	3.0	1	5
26	Signalized intersections	Saturation flow-rate model verification and validation	23	3.0	1	5
14	HCM-wide crosscutting issues	Moving America over the road—trucking's impact on highway capacity and level of service	27	2.9	1	5
15	HCM-wide crosscutting issues	Freight impact on highway capacity and level of service for urban conditions	27	2.9	1	5
22	Planning and preliminary engineering	Planning analysis of oversaturated conditions	27	2.9	1	5
12	Planning and preliminary engineering	Applying multimodal level of service to areawide analysis	30	2.8	1	5
19	Planning and preliminary engineering	Guidelines on coordinating roadway facilities with development densities	30	2.8	1	5
31	Unsignalized intersections	Development of traveler-based level of service methodologies for unsignalized intersections	30	2.8	1	5
17	Pedestrians and bicycles	Pedestrian and bicycle delay and level of service calibration	33	2.7	1	5
30	Unsignalized Intersections	Assessment of simulation tools for unsignalized intersections	33	2.7	1	5
11	HCM-wide crosscutting issues	Synthesis to determine the extent of HCM use in project prioritization and decision making	35	2.6	1	5
34	Unsignalized intersections	Unsignalized movements at signalized intersections	35	2.6	1	5
38	Urban streets	Capacity and quality of service analysis of urban local streets	35	2.6	1	5
18	Pedestrians and bicycles	Quality of service for various users of shared-use paths	38	2.3	1	5

NOTE: Priority ratings: 5 = high priority; 1 = low priority.



Note: Projects for which no project number or priority rank is presented have already been funded.

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FIGURE 1 Planned time schedule for HCM research.

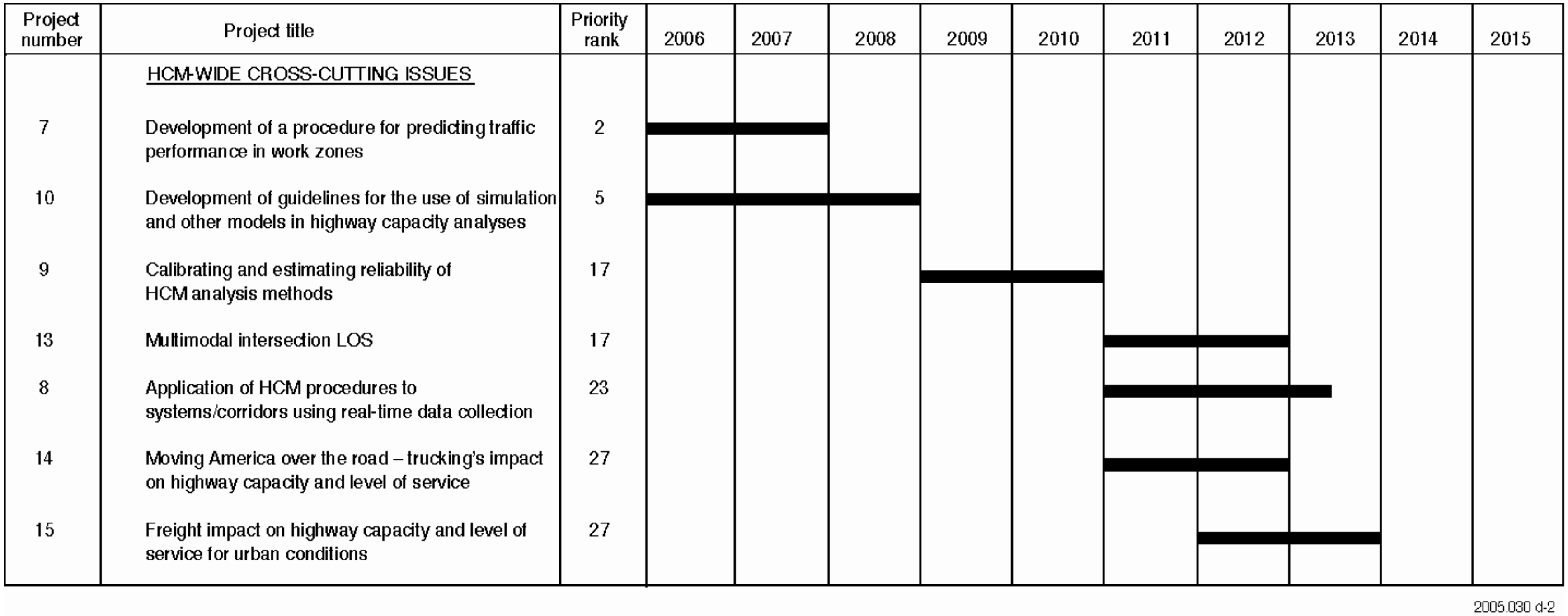

FIGURE 1 (*continued*) **Planned time schedule for HCM research.**

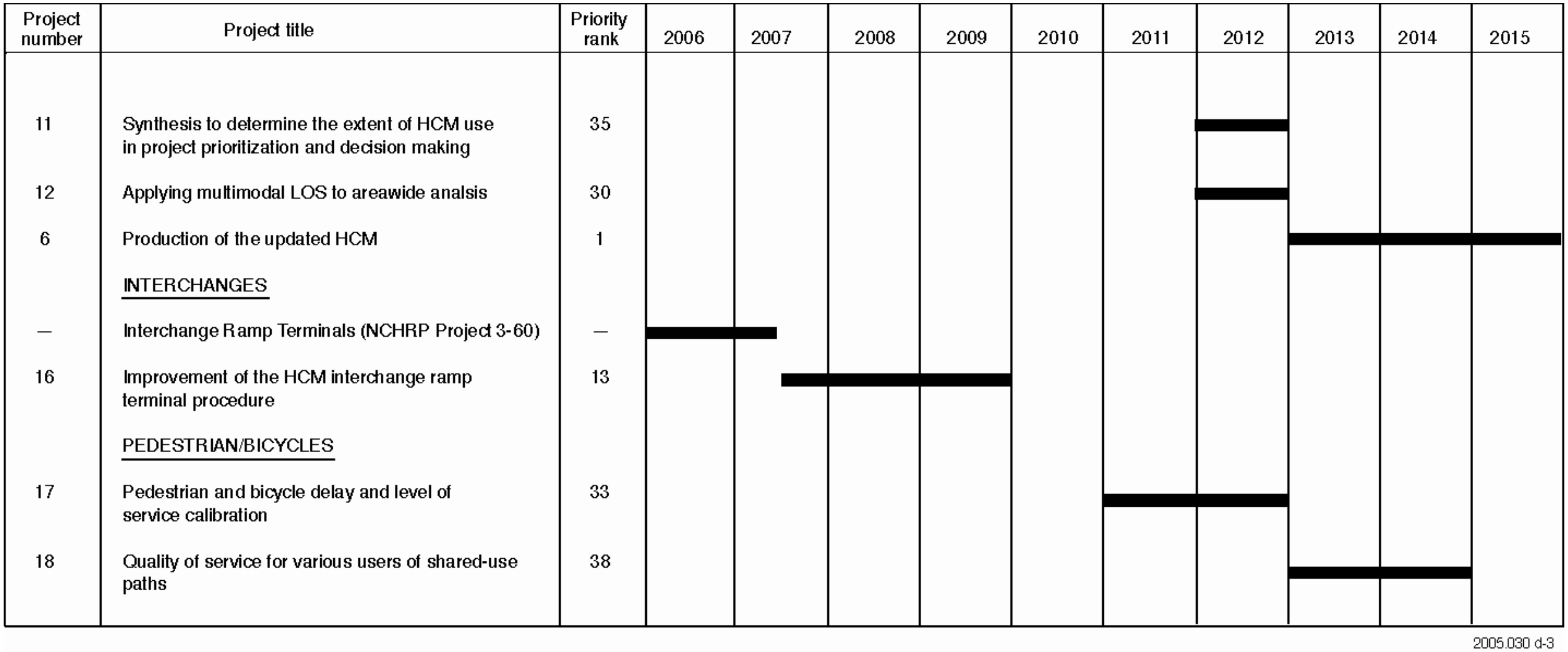

FIGURE 1 (*continued*) **Planned time schedule for HCM research.**

Project number	Project title	Priority rank	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	PLANNING AND PRELIMINARY ENGINEERING											
—	Regional and national default values for highway capacity calculations (NCHRP Project 3-82)	—	■	■								
20	Planning and preliminary engineering applications guide to the HCM	9		■	■							
21	Planning and preliminary engineering applications for freeway facilities	23							■	■		
22	Planning analysis for oversaturated conditions	27								■		
19	Guideline for coordinating roadway facilities and development densities	30							■	■		
	SIGNALIZED INTERSECTIONS											
23	Delay and queue model validation	11			■	■						
24	Development of an enhanced analytical framework for signalized intersections	13				■	■					

2005.030 d-4

FIGURE 1 (*continued*) **Planned time schedule for HCM research.**

Project number	Project title	Priority rank	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
25	Left-turn model verification and validation	21						▬	▬			
26	Saturation flow rate model verification and validation	23							▬	▬		
	TWO-LANE HIGHWAYS											
28	Traffic operational analysis methods for additional two-lane highway types	6			▬	▬	▬	▬				
27	Effects of operational treatments on two-lane highway operations	13				▬	▬	▬	▬			
	UNINTERRUPTED FLOW FACILITIES											
29	Capacity and quality of service analyses for generally uninterrupted flow facilities	6					▬	▬				
	UNSIGNALIZED INTERSECTIONS											
32	Effect of traffic demand on gap acceptance at two-way stop-controlled intersections	11			▬	▬						

2005.030 d-5

FIGURE 1 (*continued*) **Planned time schedule for HCM research.**

Project number	Project title	Priority rank	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
35	Enhancement and calibration of the two-way stop-controlled intersection capacity analysis procedure	17										
31	Development of traveler-based level of service methodologies for unsignalized intersections	30										
30	Assement of simulation tools for unsignalized intersections	33										
34	Unsignalized movements at signalized intersections	35										
	URBAN STREETS											
–	Multimodal arterial level of service (NCHRP Project 3-70)	–										
35	Modeling procedure for congested arterial facilitiies	4										
36	Operational and capacity effects of unsignalized access on urban streets	9										
37	Level of service of arterial weaving segments	13										
38	Capacity and quality of service of urban local streets	35										

2005.030 d-6

FIGURE 1 (*continued*) **Planned time schedule for HCM research.**

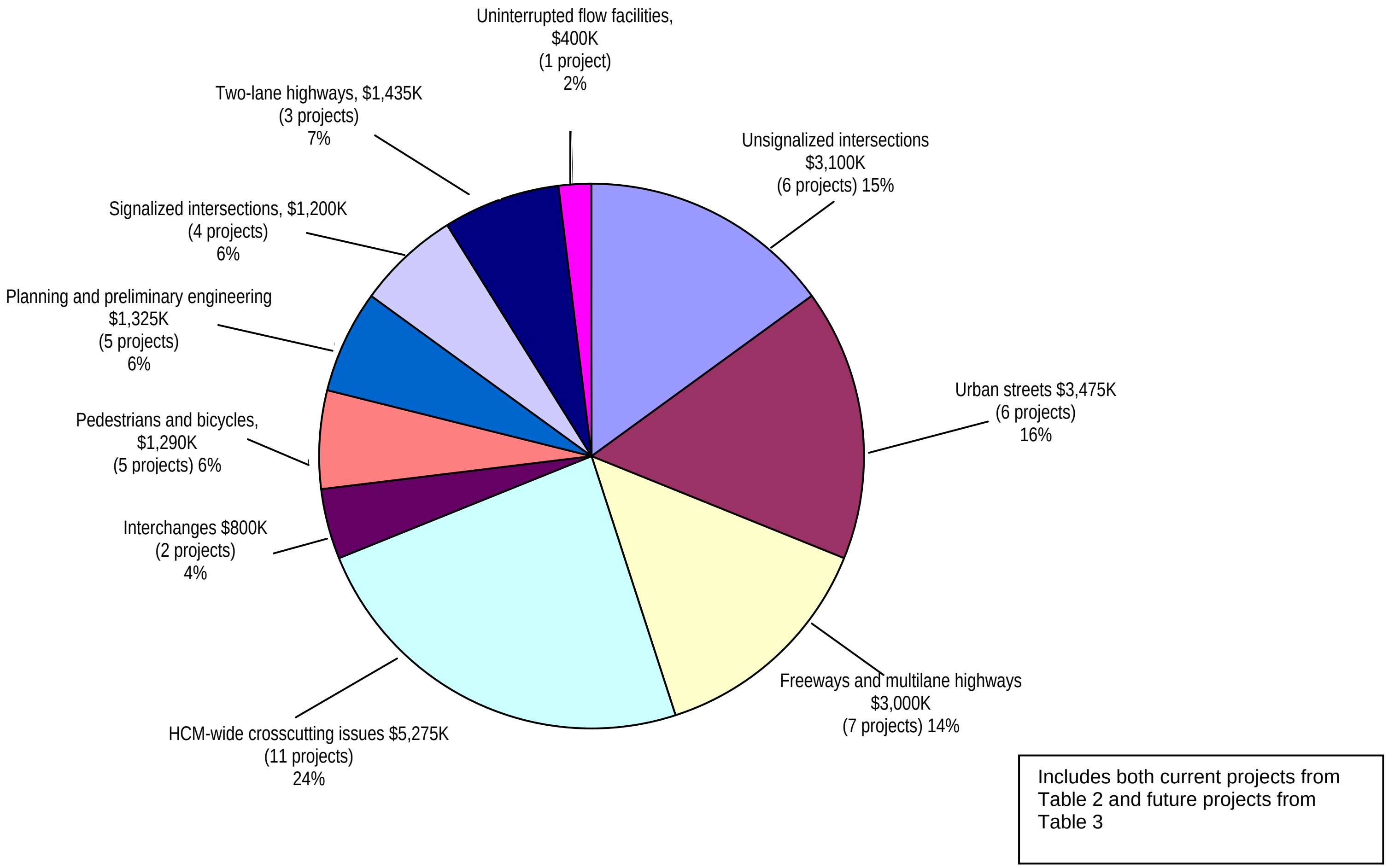

FIGURE 2 Distribution of research funding for the next edition of the HCM. Includes current projects from Table 2 and future projects from Table 3.

TABLE 7 Summary of Needed Research Funding

Topic Area	Number of Projects	Research Funding Needed for Recommended Program ($K)										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Freeways and multilane highways	5	300	350			500	400	400				1,950
HCM-wide crosscutting issues	10	1,000			600		1,200	725	1,500			5,025
Interchanges	1		500									500
Pedestrians and bicycles	2						200		250			450
Planning and preliminary engineering	4		250					475	200			925
Signalized intersections	4			350	350		200	300				1,200
Two-lane highways	2			600	800							1,400
Uninterrupted flow facilities	1					400						400
Unsignalized intersections	5			300		700	400	600	400			2,400
Urban streets			400	350		600			400			1,750
Total	38	1,300	1,500	1,600	1,750	2,200	2,400	2,500	2,750	0	0	16,000

NOTE: Funding for each recommended project is shown in the year the project would begin.

APPENDIX

Research Problem Statements

This appendix presents the 38 research problem statements that make up the planned future research program.

PROBLEM STATEMENT 1
Freeways and Multilane Highways

Enhancements to the Current Procedure for Freeway Facilities in the HCM2000

The HCM2000 contains a new procedure for estimating the operational characteristics of freeway facilities. This procedure is a collection of the procedures for basic freeway segments, ramp segments, and weaving segments. In addition to combining these segment types, the procedure allows for the analysis of oversaturated, directional freeway facilities. The aggregation of these segment types does not fully describe all freeway facilities, resulting in limitation on the current methodology. This research problem statement attempts to fill some of the known gaps and strengthen the existing methodologies.

The current freeway facilities procedure divides the facility into component segment types. An exact methodology of this segmentation has not been fully developed, particularly for those segment types that do not neatly fit into the HCM freeway segment definition. This includes the treatment of sections of freeways with long auxiliary lanes between on- and off-ramps, the treatment of closely spaced on- and off-ramps without an auxiliary lane, the treatment of lane adds and lane drops, and the minimum length of a basic freeway segment.

Research conducted during the initial development of the freeway facilities procedure showed that the weaving procedure produced the least reliable results of the segment types when compared with field observations. The weaving procedure should be enhanced to better estimate the quality of service on freeway facilities that contain weaving segments.

Often volume data collected for the analysis of freeways comes from loop or other detector counts that are part of a freeway management system. These volumes do not necessarily reflect the demand, particularly under congested conditions, because of possible metering of the demand upstream and queuing within the system. A procedure to estimate demand from volume counts should be developed to expand the use of the freeway facility procedure.

The impacts of limited off-ramp capacities are not currently included in the freeway facilities procedure. This impact might be either the capacity of the ramp segment proper or the capacity of the intersection at the surface street ramp terminal.

The current ramp segment procedures do not provide an analysis tool for the evaluation of major merges and diverges where there is a lane add or drop. The present simplifying assumption is that these segments operate most closely to a basic freeway segment. This should be tested and a new procedure developed if necessary.

In addition, the selection of appropriate performance measures reflecting traveler perception of quality of service should be evaluated. Many highway agencies are focusing on reliability-based measures of system performance. The HCM2000 does not suggest specific service measures for use in analyzing freeway facilities. The recommended research would seek to gain insight from the traveler population to identify appropriate service measures and thresholds.

Research Objectives

The primary objective of this research would be to enhance the current HCM freeway facilities procedure to analyze the situations described above.

Research Proposed

The following potential tasks should be considered:

1. Develop a methodology for segmenting a freeway facility into homogenous freeway segments that can be analyzed by separate procedures.
2. Improve the accuracy of the current weaving procedure.
3. Determine the operational characteristics of atypical freeway segments (e.g., long freeway segments between an on-ramp and off-ramp with an auxiliary lane, short freeway segments between an on-ramp and off-ramp without an auxiliary lane, minimum length of basic segments)
4. Create a procedure for estimating traffic demands from segment flows.
5. Determine the impacts of off-ramp capacity restraints of freeway operations.
6. Determine the operational characteristics of major merge and diverge segments.
7. Determine appropriate service measures and thresholds from a traveler's perspective.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2 years

PROBLEM STATEMENT 2
Freeways and Multilane Highways

Inclusion of Multimodal and High-Occupancy Vehicle Facilities in the HCM Freeway Facilities Procedure

The HCM2000 contains a new procedure for estimating the operational characteristics of freeway facilities. This new procedure is a major enhancement over the individual freeway segment analyses in the HCM since this procedure now can analyze freeways as a system and includes an analysis of oversaturated conditions. An enhancement that would greatly increase its usefulness is the inclusion of multiple modes on freeway facilities, in particular HOV facilities.

The current HCM procedure can analyze exclusive HOV facilities by making a simplifying assumption that these exclusive facilities operate in the same manner as typical freeway lanes with no interaction with other traffic. Normal HOV lanes cannot be analyzed by the current procedure. HOV lanes are lanes adjacent to general lanes without any physical separation. Inclusion of all types of HOV facilities into the analysis of freeway facilities will be of great use to planners, designers, and operators of freeways worldwide. HOV facilities have grown in popularity as a tool to make more efficient use of existing freeway corridors. An accurate and comprehensive analysis procedure can help engineers quantify the benefits and guidelines for implementing various HOV facilities.

Research Objectives

The primary objective of this research would be the creation of a supplement to the current HCM freeway facilities procedure to analyze HOV facilities.

Research Proposed

The following potential tasks should be considered:

1. Determine the difference in traffic operations between exclusive separate HOV facilities and typical HOV lanes.
2. Determine the assignment of HOV vehicles to HOV and non-HOV facilities at various decision points along a freeway corridor.
3. Quantify the influence of adjacent HOV and non-HOV facilities on each other. This influence should focus on the physical points of contact between the two facility types. If other influences are discovered (e.g., weaving), they should be analyzed as well.
4. Develop a procedure for analyzing the operation of both HOV and non-HOV lanes. The impact of ramps to and from the freeway should be quantified on both lane types. This influence should include the distance from ramps where vehicles attempt to enter or leave an HOV from a ramp. The procedure should also include the operation of HOV bypasses at metered on-ramps. This influence my include HOV and non-HOV vehicles on the ramp as well as traffic on the mainline.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2 years

PROBLEM STATEMENT 3
Freeways and Multilane Highways

Oversaturated Analysis of Freeway Traffic Flow

The HCM2000 contains procedures for the analysis of both oversaturated and undersaturated conditions on freeway facilities. This is the first edition of the HCM to analyze oversaturated freeway segments. Although this was a significant improvement over previous manuals, some major areas and gaps need to be addressed.

The speed-flow curves that were developed for basic freeway sections were based on field data collected in the 1990s. These curves address only the undersaturated flow regime. While a significant amount of data representing oversaturated flow was collected, definition of a relationship in this regime was not possible because of the high variability in the data. In the HCM2000, a simple linear flow-density relationship was assumed in order to create the associated speed-flow relationship representing the oversaturated regime. This assumed relationship has not been validated with field data. A better understanding of the speed-flow-density relationship in the oversaturated regime will result in greater accuracy in estimating freeway operations under congested flow.

In addition to better definition of the oversaturated speed-flow-density relationship, additional research is needed on the apparent loss of capacity once oversaturated conditions occur. Previous research has shown that the queue discharge rate appears to be 3% to 5% less than the capacity that can be achieved in undersaturated flow. The HCM2000 does not take this reduction into account. The loss of only 3 percent of the capacity at a bottleneck can have a large impact on queue formation and dissipation.

Currently the HCM2000 procedure is limited to a single bottleneck or multiple non-interacting bottlenecks. A better understanding of traffic flow within multiple interacting bottlenecks is needed so that the HCM2000 model can be modified to provide a more realistic estimate of oversaturated flow. Multiple bottlenecks are common on many of the nation's urban freeways, and incorporation of these into the existing model would greatly increase its usefulness.

In addition to the need to address oversaturated conditions more accurately, several facility-related issues need further study. One is the minimum segment length allowed in the model. Currently, no minimum length is specified, although short segments often result in questionable results, especially when the travel time across a segment is shorter than the analysis time step. Another issue is the need to incorporate HOV lanes into the freeway facilities model. HOV facilities are often used as a demand management tool to combat congestion, and their effectiveness needs to be analyzed in the context of a freeway facility operation.

Research Objectives

The research objective is to improve and expand the HCM2000 methodologies for the operational analysis of freeway facilities in under- and oversaturated conditions.

Research Funding and Duration

Estimate of required funding: $350,000
Expected research duration: 2 years

PROBLEM STATEMENT 4
Incidents

Operational and Capacity Effects of Incidents on Freeway Systems

Highway incidents have a dramatic impact on traffic operations. Past studies estimate that for every minute of delay caused by incidents in urban freeways, as much as 8 to 10 minutes of time is required to bring the field situation back to a manageable situation, that is, to bring traffic operations back to the conditions similar to those before the incident. As a result of these impacts in urban areas around the country, there have been many efforts spent in incident management planning and developing traffic handling procedures aimed at alleviating these conditions and lessening their impacts.

To date, limited information has been obtained and little effort has been expended toward understanding the operational and capacity impacts of these nonrecurring events. For example, the HCM2000 lists only three references dealing with the topic, and two of those are already more than a decade old. Although an incident may result in shoulder or lane closures for specific time, the impact to traffic operations is significantly greater than the loss of the capacity of the single lane(s). Because of rubbernecking by approaching motorists and motorists in opposing traffic (where visibility exists) plus interactions with incident management personnel and equipment needs, additional capacity losses are experienced. In addition, the impacts to travel speeds are pronounced. It will be the purpose of this study to define the operational and capacity effects of highway incidents for access-controlled facilities.

Research Objectives

The objectives of this study are to establish a procedure that can be used to evaluate the operational effects of highway incidents along access-controlled facilities and to document the impacts for incidents of varying durations under peak and off-peak conditions. The procedure should be able to deal with the effects not only in the same direction as the incident but also for traffic on the other side of the roadway.

Research Proposed

The research needed to address the problems described in the research problem statement would include consideration of the effect of incidents for urban areas based on time of day (i.e., peak versus off-peak versus night time), portion of the freeway affected (e.g., vehicles on the shoulder, single-lane closure, two-lane closure, full closure) and duration (1 h, 2 h, etc.). The effect of incidents in rural areas should also be considered, to the extent that data are available about them. In addition, the research should address the impact of safety during the incident, and particularly the likelihood of secondary accidents or crashes, and their further effect on operations. The benefits of the research are that it will allow practitioners to estimate available levels of capacity under incident scenarios, in order to gain greater insight into traffic diversion and traffic management needs, and to permit estimation of traffic levels on potential diversion routes. All of this information will help freeway managers to plan in advance for potential incident responses.

Development of the desired procedure will require extensive contact with freeway traffic management agencies to ascertain what if any data collection they have retained for these nonrecurring events. Depending on what is available through that effort regarding base data on incidents and capacity, simulation may be a necessary part of the research analysis.

Research Funding and Duration

Estimate of required funding: $300,000
Expected research duration: 3 years

PROBLEM STATEMENT 5
Freeways and Multilane Highways

Analytical and Simulation Procedures for Modeling Components of Toll Facilities and Toll Systems

Toll roads and toll lanes share characteristics with untolled facilities but are affected by different conditions than normal highways. Toll booths and access to and from toll facilities are controlled by mechanisms that affect the efficiencies of both toll components and toll systems. The ability to evaluate the impact on traffic of the unique features of toll facilities has become more important as the number of toll roads and toll lanes increases. A procedure that identifies the capacity of and other constraints on toll facilities, as well as the level of service at access points, mainline, and toll plazas, would assist practitioners with their ability to design and operate better toll facilities. The existing HCM has limited ability to help practitioners make the important planning, design, and operational decisions that are required for toll roads.

Research Objectives

The objective of this research is to determine the procedures needed to evaluate existing or proposed toll road facilities and to assist practitioners in planning, designing, and operating toll roads.

Research Funding and Duration

Estimate of required funding: $500,000
Expected research duration: 3 years

PROBLEM STATEMENT 6
General

Production of the Updated HCM

A contractor will be needed to manage the assembly, preparation, and production of the next edition of the HCM, in much the same way as was done for the HCM2000 in NCHRP Project 3-53(6).

Research Objectives

The objectives of the research are (1) to manage the assembly, preparation, and production of the next edition of the HCM; (2) to obtain draft chapters from authors; (3) to revise the draft chapters, as needed, in response to panel and HCQS Committee comments; (4) to develop and revise worksheets, application guides, and computational examples, as needed; (5) to write or revise HCM chapters not being addressed in other projects; (6) to identify and eliminate inconsistencies within the HCM; (7) to edit the entire revised HCM to a consistent format; (8) to develop a multimedia CD or other suitable delivery format; (9) to deliver the printed and multimedia forms of the HCM to the publisher.

Research Funding and Duration

Estimate of required funding: $1.5 million
Expected research duration: 3 years

PROBLEM STATEMENT 7
HCM-Wide Crosscutting Issues

Development of a Procedure for Predicting Traffic Performance in Work Zones

Motorists frequently experience deteriorated traffic conditions caused by work zones. Highway agencies need to predict the effect of work zones on traffic performance and to design and manage work zones properly to avoid excessive delays and risk of crashes.

The current HCM2000 does not adequately address the need of the highway agencies in analyzing and designing work zones due to deteriorated traffic performance. Therefore, there is a need for developing a procedure to predict traffic performance parameters, such as capacity, delays, queues, and level of service in work zones.

Research Objectives

The research objectives of the proposed study are to develop a procedure for predicting traffic performance. Specifically, the developed procedure will determine various traffic performance measures for road sections in work zones. The performance measures will include capacity, delay, queue, and level of service. The procedure will be developed for uninterrupted facilities as well as multilane and two-lane roadways. Separate procedures will be developed for long- and short-term work zones.

Research Proposed

The research will include field data collection at a wide variety of work zones in various states throughout the country. Simulation will be considered to expand the number of studied situations if the field data are insufficient. The outcome of this research will be a procedure that predicts traffic performance measures for work zones.

Research Funding and Duration

Estimate of required funding: $600,000
Expected research duration: 2 years

PROBLEM STATEMENT 8
HCM-Wide Crosscutting Issues

Application of HCM Procedures to Systems and Corridors Using Real-Time Data Collection

State departments of transportation see the need for making better use of the real-time data being collected. They seek knowledge and/or resources to address systemwide issues. This project proposes to look at an actual system (or corridor), city, or network of roads and to identify, for example, 50 locations where performance measures would be collected. In this process the project will identify the relevant performance measures and data collection points. The collective information from the 50 locations will define the state of the system. It may be possible to tinker with the operation of some elements of the system to test any hypothesis developed.

Simulation techniques could be used to replicate the existing system and further test additional hypothesis developed. The project brings the collective wisdom or knowledge developed and contained in the HCM to a real project. In doing so, it raises awareness of any shortcomings and contributes directly to the state of knowledge and provides real assistance to traffic managers.

Research Objectives

The research brings to bear the HCM methodologies to the real-time data collection and performance measures to establish a level of system (or corridor) state of the system. It makes use of the wealth of real-time data collection and performance measures from existing applications of intelligent transportation systems. It widens the knowledge base in bringing HCM methodologies and real-time data collection to find solutions to the system and corridor problems.

Research Proposed

The following potential tasks might be considered:

1. Select a corridor.
2. Review state of real-time data collection.
3. Identify performance measures or surrogate measures obtainable from real-time data.
4. Identify locations or points for collection of data regarding performance measures.
5. Define the state of the system, including variability.
6. Relate the state of the system and verify in relation to HCM methodologies.
7. Develop and verify the real-time simulation of the system.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 9
Areawide

Procedures for Calibrating and Estimating the Reliability of HCM Analysis Methods

Almost every analysis method contained in the HCM can be customized to more accurately reflect local driving conditions through a calibration process, thereby significantly increasing the reliability and accuracy of the analysis results. Although general statements to this effect are included within the HCM, no specific procedural guidance is provided on how to undertake the calibration process, nor is any such guidance incorporated into the procedures for application. As a result, many practitioners continue to use generic and standard default values for key input parameters, or they apply individually developed calibration procedures that are inherently flawed.

Even after the HCM analysis methods have been calibrated to local conditions, practitioners are still left uninformed about the reliability of the various performance measure estimates that are produced. As a result, most engineering studies remain silent on this issue; decision-makers are forced either to use their own judgment or to ignore this very important factor when making key decisions on alternative transportation investment strategies. Well-defined procedures for calibrating HCM analysis methods and estimating the reliability of the analysis results will significantly improve the quality and value of information available to decision makers and will promote better and more informed decision making on transportation-related investments of all types.

Research Objectives

The primary objectives of this research will be the creation of well-defined and implementable procedures for calibrating HCM analysis methods and estimating the reliability of the analysis results.

Research Proposed

The following potential tasks should be considered:

1. For each analysis method within the HCM, identify the key input parameters that can and should be adjusted to reflect local conditions and/or driver characteristics.
2. Develop a calibration procedure for each analysis method that can be applied either to the entire system or to an individual point, segment, or facility. Such calibration procedures should be implementable for all types of projects and communities with respect to time, labor, and field data requirements.
3. Identify the key parameters in each HCM analysis procedure that can most significantly affect the reliability of the analysis results, and develop a procedure for quantifying their net effects, relying on methods that are implementable and on data that are readily available or easily obtained
4. Incorporate the recommended calibration and reliability estimation methods into the application procedures of the HCM and/or the HCM Applications Guide (HCMAG).

Research Funding and Duration

Estimate of required funding: $600,000
Expected research duration: 24 months

PROBLEM STATEMENT 10
HCM-Wide Crosscutting Issues

Development of Guidelines for the Use of Simulation and Other Models in Highway Capacity Analyses

Traffic analysts often use simulation and other models in conjunction with, or instead of, HCM procedures to evaluate traffic operational quality and estimate capacity. Such models may be used when HCM methods do not address a particular facility configuration or traffic demand scenario, when HCM techniques do not support systems analysis requirements, or when there is a need to supplement the findings of HCM analysis.

Part V was added to the HCM2000 to address some of the questions regarding the application and use of simulation and other models in highway capacity analysis. Part V discusses traffic simulation and other models and provides typical applications of such models in traffic operational analysis. The existing Part V is general in scope, however, and does not provide specific guidance on the use of such models for each facility type to conduct highway capacity analysis or to obtain capacity and level of service estimates.

Research Objectives

The objective of the proposed research is to develop materials for inclusion in the HCM to provide guidance on the use of alternative models including simulation for highway capacity and transportation operations analysis. The scope of the project will include all facility types included in the HCM. The final product of the project will be recommended revisions and additions to be included within the HCM to assist analysts in using simulation models for highway capacity analysis purposes.

Research Proposed

The proposed project should include the following tasks:

1. Conduct a literature review and highway agency survey to identify recommended practices for simulation modeling for capacity analysis;
2. Identify opportunities for enhancing existing HCM chapters to clarify definitions of existing HCM terms (such as capacity, delay, etc.) so that they can be obtained from a simulation model model;
3. For each HCM methodology, develop guidelines for obtaining capacity and other pertinent performance measures including service measures from a simulation model;
4. Develop recommended guidance for applying simulation models for highway capacity analysis; and
5. Develop guidelines for numerical comparisons of results obtained through a simulation model and through the HCM methods.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 3 years

PROBLEM STATEMENT 11
HCM-Wide Crosscutting Issues

Synthesis to Determine the Extent of HCM Use in Project Prioritization and Decision Making

A primary application of the HCM by transportation agencies is to assess the effect of proposed improvement projects on quality of service. However, the HCM does not address how HCM results should be used in project prioritization and decision making and does not consistently provide measures that are needed by highway agencies for this purpose. For example, transportation agencies might wish to use HCM results to rank proposed projects by delay reduction (expressed in vehicle-hours or person-hours) or by delay reduction per dollar of construction cost. In decision making, transportation agencies might choose to value delay reduction differently for different levels of service. The HCM should include a new section on project prioritization and decision making. All existing and future HCM methodologies should be reviewed and improved to assure that they provide the measures needed by transportation agencies for project prioritization.

Research Objectives

The objective of this research is to assess the extent to which the HCM is being used by state departments of transportation, metropolitan planning organizations, transit providers, and local governments in the prioritization of transportation projects and in the decision-making processes for which projects are selected.

Research Proposed

The following potential tasks should be considered:

1. Conduct a review of the HCM to identify those measures that can be used in the project prioritization and decision-making process. Review other related literature such as the AASHTO Red Book to identify additional measures.
2. Develop a contact database of project planning and programming directors for state departments of transportation, metropolitan planning organizations, and selected local governments. Prepare an introductory letter explaining the purpose of the synthesis and establishing the correct contact person.
3. Develop a web-based survey instrument to identify the extent to which the HCM is being used in project prioritization and decision making. Identify the most commonly used performance measures, both HCM and non-HCM. Identify other desired measures used by state and local agencies.
4. Compile survey results and perform follow-up contacts when necessary to obtain additional information on existing or desired measures.
5. Recommend additional actions to be taken. Options could include
   - Conducting additional, more detailed research, either independently or as part of another funded research project, to advance the body of knowledge on this subject,
   - Including the results as a new chapter in a future revision of the HCM, and
   - Developing a project prioritization and decision-making guide or include such a guide as an addendum to the HCMAG.
6. Summarize the results and document in a research synthesis.

Research Funding and Duration

Estimate of required funding: $25,000
Expected research duration: 1 year

PROBLEM STATEMENT 12
Areawide

Applying Multimodal Level of Service to Areawide Analysis

The need for funding for new highways and capacity improvement projects far exceeds the available resources. The practical reality is that we can no longer build our way out of congestion. Increasing the ability to manage and operate the system, reducing demand through better coordination of land use and transportation, and providing choices to travelers for using alternate modes are major themes in the Transportation Equity Act for the 21st Century (TEA-21).

Many state governments have enacted legislation that guides development in harmony with transportation and other infrastructure. This type of development favors pedestrian, bicycle, and transit modes. This type of development can be used to promote mixed-use, interconnection, and dense land uses that are pedestrian and transit friendly in urban form and design.

Developers of projects of various sizes are increasingly seeking multimodal options to reduce or eliminate their anticipated impacts on the transportation network in other areas.

Current NCHRP Project 3-70 would provide a building block for facility level multimodal level of service.

A significant amount of literature exists that considers the potential to moderate travel demand through changes in the built environment. This literature is summarized in an article by Reid Ewing and Robert Cervero in *Transportation Research Record 1780* (2001). It demonstrates the responsiveness of travel demand to changes in density, diversity, design, and regional accessibility. The literature on the connection between land use and transportation suggests that traditional neighborhoods, with high density, mixed land use, a gridded street network, and transit-oriented design features, have the potential to reduce the number of vehicle trips taken and the vehicle-miles of travel.

Research Objectives

The research will develop a methodology for areawide multimodal transportation planning. It will develop multimodal areawide conceptual frameworks and tools for the analysis and planning of development serving all modes of transportation rather than over relying on the automobile.

Research Funding and Duration

Estimate of required funding: $200,000
Expected research duration: 1 year

PROBLEM STATEMENT 13
HCM-Wide Crosscutting Issues

Multimodal Intersection Level of Service

Throughout the United States there is a desire to evaluate the quality of transportation service of roadways from a multimodal perspective. TEA-21 calls for the mainstreaming of transit, pedestrian, and bicycle projects into the planning, design, and operation of the U.S. transportation system. Largely in response to TEA-21, NCHRP Project 3-70 (Multimodal Level of Service for Urban Streets) has been funded and is nearing completion. Whereas that project concentrated on integrating modal level of service analyses at the facility level and on incorporating those techniques into the HCM, it did not concentrate on multimodal interactions at the intersection level, where the greatest amount of interaction among the modes occurs.

The current signalized intersections and unsignalized intersections chapters of the HCM2000 essentially only address the level of service of the automobile mode. Automobiles, buses, pedestrians, and bicycles are all potential users of urban street intersections. At urban street intersections the modes also interact with each other such that improvements in quality of service to one mode may improve or lower the quality of service for another mode.

Compounding the problem of an integrated multimodal approach to evaluate intersections is relatively little research conducted on how actual travelers evaluate quality of service at intersections. Level of service for motorized vehicles in the HCM2000 is based on control delay, but that service measure has not been verified. Recent pedestrian and bicycle research in Florida has involved actual pedestrians and bicyclists in determining level of service thresholds at intersections. Initial conclusion is that the level of service thresholds among the modes do not align well. For example, LOS D for travelers in motorized vehicles may be considered quite acceptable, whereas for nonmotorized vehicle travelers, LOS D may be considered quite bad.

Research Objectives

The objective of this research project is to develop a multimodal urban street intersection level of service analysis methodology and to document the methodology for the next update of the HCM. Major research activities would involve

- Developing and validating quality and level of service performance measures and thresholds for travelers in motorized vehicles based on actual traveler perceptions,
- Developing and validating quality and level of service performance measures and thresholds for pedestrians and bicyclists based on actual traveler perceptions,
- Developing a simultaneous, integrated multimodal urban street intersection analysis methodology, and
- Documenting the methodology for use in the next update of the HCM.

Research Funding and Duration

Estimate of required funding: $500,000
Expected research duration: 2 years

PROBLEM STATEMENT 14
HCM-Wide Crosscutting Issues

Moving America over the Road—Trucking's Impact on Highway Capacity and Level of Service

Freight traffic growth has contributed to the growth in vehicle-mile traffic as truck traffic has increased at a rate faster than person travel. This disproportionate growth in truck volume can be attributed to a number of factors including the shift of many freight items from rail and other modes to truck and the changes in the economy and business practices, such as just-in-time deliveries of inventory items, that increase delivery frequencies. At the same time an increasing proportion of the highway system is undergoing rehabilitation without increasing capacity. During construction, work zones can have less than ideal conditions from the passenger car perspective in terms of narrower lanes, but the impact on trucks and their influence on smaller vehicles through the work zone are undetermined.

Depending on the context, a large truck can consume the equivalent of several cars worth of roadway capacity because of its physical size, acceleration, and other performance characteristics. The HCM, the world's leading source for highway capacity and level of service determinations, provides fairly constant passenger-car equivalence factors by roadway type. For example, the factors for level two-lane highways are 1.1 and for freeways and multilane highways 1.5. A growing number of professionals question these values, especially under congested conditions. In stop-and-go traffic, large tractor-trailers have a much slower start up time than passenger cars. Especially relevant are the equivalencies of trucks in work zones.

There is a growing need to quantify the actual effects of trucks on highway facilities that are either purely long-haul or dual purpose in their need to serve both commuters and long-haul freight. With more of the national system being physically or financially constrained each year, solutions for effectively moving freight traffic are needed. The ability to better quantify the impacts of the trucking fleet on capacity and quality of service as well as to provide alternative solutions in terms of routing, timing, or exclusive use facilities would aid planners and engineers in providing more reliable and potentially safer travel conditions.

With increasing numbers of trucks on the nation's roadways, the impact of heavy vehicles has become a more significant factor in level of service analysis. Essentially, the HCM methodologies may be underreporting levels of service on facilities with significant truck volumes. Furthermore, level of service is primarily reported in terms of passenger car driver perceptions. However, truck drivers may experience different perceptions. For example, truckers may evaluate the effect of narrow lanes and stop-and-go traffic far worse than passenger car drivers or their evaluation criteria may be based on reliability rather than speed.

Research Objectives

The objective of this research is to develop improved, nationally accepted capacity and level of service techniques that better account for trucks with the intent of updating the HCM.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature review of the impact of trucks on essentially uninterrupted flow highway facilities, how truck drivers evaluate level of service, and operational experience with truck-only facilities.
2. Create a typology of roadway types and elements that are affected by freight movements. For example, roadway types may be freeways and multilane highways, two-lane highways, and interrupted flow arterials with widely spaced intersections. Roadway elements may include grades, truck lane restrictions, frequency of access via ramps or intersections or work zones.
3. Collect field data from around the nation reflecting the impact of truck movements, truck types, roadway types, and roadway elements on similar facilities with and without work zones to the extent possible. If truck-only facilities exist with conditions reasonably similar to U.S. driving conditions and geometry, obtain operational capacity and level of service information.
4. Assess trucker perceptions of quality of service based on different traffic, roadway, and control conditions, as well as operating results.
5. Compare the results with procedures in the HCM2000. Coordinate with the HCQS Committee. Recommend new equivalence factors for use in the HCM.
6. Develop technical reports summarizing findings and recommendations.

Research Funding and Duration

Estimate of required funding: $300,000
Expected duration: 2.0 years

PROBLEM STATEMENT 15
HCM-Wide Crosscutting Issues

Freight Impact on Highway Capacity and Level of Service for Urban Conditions

Freight traffic growth has contributed to the growth in vehicle-mile traffic as truck traffic has increased at a rate faster than person travel. Trucks also have a disproportionate impact on roadway capacity, particularly on networks dominated by arterials and local streets. Depending on the context, a large truck can consume the equivalent of several cars worth of roadway capacity because of its physical size, acceleration, turning radius,, and other performance characteristics.

This disproportionate growth in truck volume can be attributed to a number of factors including the dispersion of population and employment, the shift of many freight items from rail and other modes to truck, and the changes in the economy and business practices, such as just-in-time deliveries of inventory items, that increase delivery frequencies.

The HCM, the world's leading source for highway capacity and level of service determinations, provides fairly constant passenger-car equivalence factors by roadway type. For example, the equivalence factor for signalized intersections is 2.0. A growing number of professionals question these values, especially under congested conditions. In stop-and-go traffic, large tractor trailers have a much slower start-up time than passenger cars. Especially relevant are the equivalencies of trucks in areas where loading zones are present.

There is a growing need to quantify the actual effects of trucks on our urban areas to support the ability to safely and efficiently move goods and people in areas where expansion of roadways is generally not an option. Planners and engineers need to be able to more effectively quantify the impacts of locating shipping-intensive land uses and improve the inputs to the tools used to manage traffic.

With increasing numbers of trucks in our cities and towns providing goods more frequently, there are three vehicular occupant groups to consider. One group in the traditional perspective of the HCM is composed of auto drivers and the impact of trucks on delay and travel reliability. The second group consists of the users of the *Transit Capacity Manual* and transit users; their concern is the delay and safety impacts from trucks both along routes and at bus stops. The third group is truck drivers who are concerned with reliability, access, and safety during on-street loading and unloading activities.

Research Objectives

The objective of this research is to develop improved, nationally accepted capacity and level of service techniques that better account for trucks in urbanized areas with the intent of updating the HCM. As a secondary objective, the research should inform users of the *Transit Capacity*

Manual what topics might be pursued on the interaction between truck and bus activities in urbanized areas.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature review focusing on two areas: the impact of trucks on arterials and intersections and how truck drivers evaluate level of service.
2. Create a typology of roadway types and elements that are affected by freight movements. For example, roadway types may be Class I arterials or two-lane highways interrupted by signals. Roadway elements may include variable effects of lane width by roadway type, turning radius for right turns, and presence or absence of loading zones.
3. Collect field data from around the nation reflecting the impact of truck movements, truck types, roadway types, roadway elements.
4. Assess trucker perceptions of quality of service based on different traffic, roadway, and control conditions, as well as operating results focusing on pick-up and delivery as opposed to long haul activities.
5. Compare the results with procedures in the HCM2000. Coordinate with the HCQS Committee and the Committee on Transit Capacity and Quality of Service. Recommend new equivalence factors and or additional variables for use in the HCM's interrupted flow methodologies.
6. Develop technical reports summarizing findings and recommendations.

Research Funding and Duration

Estimate of required funding: $500,000
Expected duration: 2.5 years

PROBLEM STATEMENT 16
Interchanges

Improvement of the HCM Interchange Ramp Terminal Procedure

Chapter 26 of the HCM2000 is in the process of being rewritten as a complete chapter—with an analytical method of determining capacity and level of service—as part of ongoing work in NCHRP Project 3-60. It is anticipated that this revision will be completed for distribution as part of the HCM, in approximately 2005. There are areas of need that are not being addressed in NCHRP Project 3-60 and will need to be addressed in further revisions of HCM Chapter 26. These areas to be included are as follows:

- Interchange ramp terminal forms that are of general interest, such as roundabouts;
- Ramp meters;
- Closely spaced intersections;
- Actuated versus fixed-time operation;

- Impact of geometry on operation;
- HOV bypass lanes;
- High design impacts on flow rates;
- Arterial weaving;
- Lane use;
- Simulation update; and
- Example problems update.

Research Objectives

The objective of the research is to develop a revised version of HCM Chapter 26 to meet the needs identified above.

Research Funding and Duration

Estimate of required funding: $500,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 17
Pedestrians and Bicycles

Pedestrian and Bicycle Delay and Level of Service Calibration

The HCM includes procedures to estimate level of service for pedestrians and bicyclists based upon control delay at signalized and unsignalized intersections. The delay models for signalized intersections are based upon an assumption of random arrivals with no influence from signal coordination. Recent research has shown that pedestrian and bicycle arrivals are influenced by signal coordination and that the coordination effect can have a large positive or negative influence upon delay. The effects of two-stage crossings for pedestrians (either using a pedestrian refuge island or crossing both streets at an intersection) are also not currently addressed. Better modeling of pedestrian and bicycle delay could help traffic engineers and planners provide for these modes and make trade-offs between delay for pedestrians, bicyclists, and motorists.

Research Objectives

The objective of this research is to calibrate pedestrian and bicycle delay models for the HCM to accurately reflect the effects of pedestrian and bicyclist decision making and the effects of signal coordination.

Research Funding and Duration

Estimate of required funding: $200,000
Expected research duration: 2 years

PROBLEM STATEMENT 18
Pedestrians and Bicycles

Quality of Service for Various Users of Shared-Use Paths

Bicyclists typically travel about four times faster than pedestrians. Because of this large difference in speed, bicyclists and pedestrians often conflict with each other on shared use paths. The HCM includes procedures for determining the level of service from both the bicyclist and the pedestrian perspectives for shared bicycle and walking paths. The current HCM addresses only these two modes on shared use paths. Many paths include joggers, in-line skaters, skateboarders, and other users with varying speeds and desires for space on the path. When sufficient space is not available, conflicts between users are frequent.

FHWA recently sponsored a study focused on users' perceptions of various features found on existing shared-use paths across the country, including path width, type, striping, adjacent surface texture, adjacent vegetation, and alignment. This study's extensive use of focus group feedback will provide guidance on design features that attract users to desirable shared-use paths. However, this study did not address the issue of establishing specific quality of service measures for shared-use path users. It is clear, however, that path width is a key element in users' perceptions of their experiences while on a specific path.

Research Objectives

The objective of this research is to develop and test a method to relate path width to a quality of flow measure and levels of service for different mixes of shared path users.

Research Funding and Duration

Estimate of required funding: $250,000
Expected research duration: 2 years

PROBLEM STATEMENT 19
Planning and Preliminary Engineering

Guidelines on Coordinating Roadway Facilities with Development Densities

Traffic congestion is an increasing problem along urban roadway facilities in the United States. Analysis of roadway congestion is typically based on individual facilities. There are many tools to analyze the potential capacity of an individual roadway facility but few tools available to analyze corridors or networks of roadway facilities.

It is well known and understood that an urban or suburban area must have a system of roadways to serve its travel needs. These include freeways, arterial streets, collector streets, and local streets. These facilities must be planned in a logical fashion in order to provide access to adjacent developments and capacity for through trips. Research is needed to plan new development and to provide insight into the traffic congestion problems in areas that are already developed. The following questions need to be addressed:

- From the point of view of roadway capacity, what is the required spacing of freeways, arterial streets, and collector streets required to serve typical suburban development?
- How would roadway spacing requirements change in high-density urban areas and areas with extensive public transit systems?

Research Objectives

The objective of this research project is to develop recommendations for the spacing of roadway facilities for the following types of roadways:

- Freeways,
- Arterial streets,
- Collector streets, and
- Bicycle, pedestrian, and transit facilities and service.

Roadway spacing recommendations would be developed for the following types of land use development:

- Typical suburban U.S. development,
- Urban development that is well served by public transit, and
- Neotraditional mixed-use development.

The first phase of the research would develop roadway spacing guidelines based on hypothetical land use assumptions. The second phase of the research would select four examples of suburban development and four examples of urban development in locations throughout the United States to be used as test cases. On the basis of current traffic conditions, roadway facility spacing, traffic levels, and roadway congestion levels would be evaluated in each of the test cases to determine whether roadway spacing is adequate. The results from the test cases would be compared with the recommendations based on hypothetical land use assumptions to evaluate the accuracy of the recommendations and provide additional insight into the problem.

Research Funding and Duration

Estimate of required funding: $300,000
Expected research duration: 2 years

PROBLEM STATEMENT 20
Planning and Preliminary Engineering

Planning and Preliminary Engineering Applications Guide to the HCM

An HCM applications guide has been developed in NCHRP Project 3-64. This guide addresses a broad set of potential HCM applications with emphasis on applications related to design and operations. The development of a similar guide focusing on planning and preliminary engineering applications of the HCM is recommended.

Research Objectives

The objective of the recommended research is to develop an HCM planning and preliminary engineering applications guide.

Research Funding and Duration

Estimate of required funding: $250,000
Expected research duration: 2 years

PROBLEM STATEMENT 21
Planning and Preliminary Engineering

Planning and Preliminary Engineering Applications for Freeway Facilities

The HCM2000 features a new chapter on freeway facilities that combines the analyses of basic freeway segments, ramps, and weaving areas. It is an operational methodology building on the operational analysis techniques of the segment chapters. Although it seems to be an excellent operational tool, it appears to have little value as a planning tool.

Unlike other HCM facility analyses, the freeway analysis does not provide an easy way to combine segment analyses for the determination of a freeway facility's level of service. Having a preliminary engineering method of analysis is especially important for reporting the quality of service of freeways at the state and national levels, for possible funding allocations, and when detailed geometrics and traffic volumes are not known.

Research Objectives

The objective of this research project is to develop freeway facility planning and preliminary engineering applications and to document these applications in the next update of the HCM. Features of the planning and preliminary engineering applications should tentatively include (but not be limited to)

- A structure to allow the assessment of possible future improvements to be analyzed;
- Level of service thresholds;
- A structure to allow development of service volume tables;
- Approximately four classes of freeways, possibly broken down by density of interchanges, free flow speed, and/or tolled;
- A structure to combine ramps and weaving areas into interchange areas;
- Consideration of toll plazas; and
- Sensitivity to truck movements.

Research Funding and Duration

Estimate of required funding: $175,000
Expected research duration: 2 years

PROBLEM STATEMENT 22
Planning and Preliminary Engineering

Planning Analysis of Oversaturated Conditions

This research will provide additional tools to analyze and quantify oversaturated traffic conditions in planning applications. The goal will be to provide tools that can be used in a planning context where only basic parameters are known and it is necessary to have only a general qualification of the degree of congestion.

Research Objective

The objective of this research is to develop a methodology for quantifying degrees of congestion in a planning context.

Research Proposed

Review currently available methodologies to quantify oversaturated conditions. Evaluate their effectiveness in terms of accuracy, ease of use for planners, and ability to provide useful information to decision makers. It should include proposed use of existing methodologies or new methodologies that would meet the research objective. In order to be useful in a planning context, the methodology would have as inputs lane geometry, peak hour traffic, and other basic information.

Research Funding and Duration

Estimate of required funding: $200,000
Expected research duration: 1 year

PROBLEM STATEMENT 23
Signalized Intersections

Delay and Queue Model Validation

Since 1985, there have been many changes to the methodologies included in the signalized intersection chapter of the HCM. Most of these changes have been based on research conducted on isolated issues such as saturation flow rate, lost time, and actuated signals. Although each contributing study has helped to enhance the methodology, there has been no comprehensive analysis of the cumulative impact of these piecemeal changes. Various issues including uniformity across different facilities and different areas (rural versus urban) have been identified and need to be studied in greater detail. More specifically, practitioners and researchers have identified a need to evaluate the accuracy and reliability of two key performance measures reported by HCM: delay and queuing.

The signalized intersection chapter of the HCM2000 includes the effects on delay of (1) metering, (2) actuated controller settings, and (3) time-dependent queuing. The effects of platooned arrival patterns have also been recognized for some time and are represented in the HCM methodology by simple categories of user input arrival types. The measure of effectiveness used for level of service was modified from stopped delay to control delay, which includes time spent decelerating, accelerating, and moving in queue (a simple factor of 1.3 was used). Field validation of the delay model for varying conditions is limited.

The HCM2000 represents the first edition of the HCM that includes back-of-queue estimates for signalized intersections. The procedures for estimating back of queue included in the HCM2000 are based on work performed by R. Akçelik (*A Queue Model for HCM2000*, Technical Note, ARRB Transport Research Ltd., Australia). While minor modifications have been made to the back-of-queue procedures to correct identified discrepancies since the initial release of the HCM2000, there remain deficiencies and shortcomings associated with the queue modeling procedures.

A summary of a few of the limitations, deficiencies, and concerns related to the delay and queue models in the HCM are described below:

- Limited field validation has been performed for the delay and queue models at intersections operating over capacity.
- The methods of estimating effects to delay caused by upstream signals are inconsistent across chapters of the HCM. The unsignalized intersection analysis procedures estimate the effect of upstream signals based on user estimates of upstream signal parameters, while the signalized intersection procedures rely on a user estimation of arrival type.
- Direct comparisons of performance at different intersection types (signalized, two-way stop, all-way stop, roundabout, etc.) are often desired; however, geometric delays associated with traveling through an intersection are not accounted for. A method of providing a similar comparison of delay between intersection types is needed.
- Akçelik's queue model was developed and intended for use with an individual lane model such as aaSIDRA. In order to be compatible with the HCM2000 procedures, which estimate saturation flow, delay, and capacity for lane groups, the lane utilization factor described in Chapter 16 of the HCM2000 was introduced into the back-of-queue equations to provide estimates for multiple-lane lane groups. Field observations clearly show in certain cases that the distribution of vehicle queues across multiple lanes of a lane group is not reflective of the default values for lane utilization provided in the HCM.
- Before implementation in the HCM2000, Akçelik's back-of-queue model was validated against simulation data produced from Model C. Limited validation has been performed using field data. The reliability of the queue estimates is largely unknown.

Research Objectives

The primary objective of the research is to evaluate the framework of the delay and queue models that are currently used in the HCM analysis of signalized intersections and recommend improvements to the models if needed.

Research Proposed

The following potential tasks should be considered:

1. Review the delay and queue models currently used in the HCM and identify inconsistencies and shortcomings.
2. Conduct field studies to measure delay and queue length at isolated and nonisolated intersections for different volume, geometric, and signalization conditions. The studies should include coordinated and uncoordinated signals and intersections with pretimed and actuated control. The studies should also address the influence of approach speeds on control delay.
3. Compare the model estimates of delay and queue length with the study values and identify inconsistencies. Inconsistencies may help identify changes to the methodology that have been considered mutually exclusive but which may actually be complementary and should be incorporated accordingly.
4. Recommend modifications or improvements to the methodology for any identified inconsistencies.

Research Funding and Duration

Estimate of required funding: $350,000
Expected research duration: 2 years

PROBLEM STATEMENT 24
Signalized Intersections

Development of an Enhanced Analytical Framework for Signalized Intersections

As the HCM procedures for estimating capacity at signalized intersections have evolved over the years, issues have been raised regarding their accurateness and suitability for certain situations. One issue is the appropriateness of the lane group concept and the application of the lane utilization factor to reflect imbalances across lanes. A second issue is the ability of the procedures to adequately represent signal operations for actuated controllers. A third issue is the lack of ability of the procedures to account for short lanes and effects of queue spillback between closely spaced intersections.

The current analysis procedures for signalized intersections and interchanges are based on the concept of lane groups. A lane group is, by definition, a lane, or adjacent set of lanes that accommodates one or more traffic movements in a homogeneous manner. The simplifying assumption of homogeneity was considered essential to the manual analysis procedures of the 1985 HCM. It has long been recognized that traffic movements sharing a lane (e.g., through movements and left turns) are seldom, in fact, homogeneous. This simplifying assumption has an adverse effect on the accuracy and reliability of the results for situations where nonhomogeneous conditions exist.

With respect to signal operation, the HCM2000 procedures for evaluating signalized intersection capacity and level of service are based on an assumed pretimed controller operation. Intersection operations are evaluated in terms of a fixed sequence of signal phases with each phase typically serving several traffic movements and each having a fixed duration. In contrast, many signal controllers in use today are based on a traffic-actuated operation where each phase is typically assigned to only one left-turn or through-traffic movement, where phases can run concurrently, and where three controller settings (i.e., passage time, minimum green, and maximum green) are used to regulate phase duration. The HCM procedures accept as input the pretimed phase durations and their sequence of presentation. They do not directly accept actuated controller settings or phase assignments. This provides a limitation on the capacity analysis and the way in which signal operation is included in the analysis. As a result, the HCM procedures are not fully applicable to the wide range of conditions commonly encountered by practicing engineers.

On many urban arterial and collector facilities, signalized intersections are often located in close proximity such that the operation of one intersection influences the operation of the other; for example, when a queue spillback occurs from a downstream intersection and prevents queue discharge from the upstream intersection. In addition, vehicle queues may block relatively short left- or right-turn bays, effectively reducing the capacity of the turn movements.

Additional examples of the limitations imposed by the current analysis procedures include

- Shared-lane permitted left and right turns are unable to deal realistically with the problem of equilibrium between a shared lane and an adjacent through lane.
- Lane utilization factors, now empirically derived, also have acknowledged weaknesses. The current HCM version suggests caution in using these factors, especially at high levels of saturation.
- Lane imbalance effects due to upstream and downstream influences are not accounted for in the current HCM procedures.
- Traffic-actuated control cannot be modeled realistically in a homogeneous lane group because a queue extending to the detector in either lane will exert a controlling influence on the signal timing parameters, which are important to the estimation of capacity and delay.
- The HCM2000 procedures assume that vehicle queues on an approach do not adversely affect approach operations. The effect of queue spillback from turn bays into adjacent through lanes is not considered.
- The effects on saturation flow and capacity resulting from queue spillback associated with closely spaced upstream and downstream intersections are not accounted for in the current analysis procedures.
- The HCM2000 suggests that the signalized intersection procedures may be used in an iterative manner to optimize the signal timing to minimize delay; however, the current empirical model for shared-lane left turns does not produce a stable convergence in an iterative procedure.
- All of the issues stated above apply to the interchange and ramp terminal chapter as well as the signalized intersection chapter. In most cases, these effects may be more critical at interchanges involving closely spaced intersections because of queues that may back up unequally in different lanes.

Research Objectives

The primary objective of this research is to develop a comprehensive analysis framework that addresses the known shortcomings of the HCM procedures. The framework could be applied as a supplement to the current HCM procedures or could be recommended as a replacement.

Research Proposed

The following potential tasks should be considered:

1. Review current HCM lane group procedures and substantiate the shortcomings of the model for approaches with nonhomogeneous conditions.
2. Review existing lane-by-lane analysis procedures and examine how the models address volume distribution across lanes. The effect of upstream and downstream influences on pre-positioning should be addressed. Alternative analysis methods, such as time-scan versus event-scan, and the subgroup method for evaluating saturation flow should be considered in the review. The review should document the advantages and disadvantages of each approach.
3. Review existing procedures for evaluating and optimizing signal control for actuated signals. The procedures should accept commonly used inputs including passage time, minimum green, and maximum green. The procedures should account for phase skips, phase dwell, and pedestrian actuations. The procedures should also address detector layout and operation.
4. Review existing procedures for addressing queue spillback from turn bays into adjacent through lanes, blockage of short lanes from through lanes, and queue spillback related to upstream and downstream intersections.
5. Develop a recommended framework for a signalized intersection analysis procedure that addresses Items 1 to 4, above. The procedures should apply to signalized intersections of all common geometric and control types. The procedures should be capable of being incorporated into systemwide analysis methods of analysis for arterials and highway facilities.
6. Identify and conduct research to develop and validate the procedures outlined above in Item 5.

Research Funding and Duration

Estimate of required funding: $350,000
Expected research duration: 2 years

PROBLEM STATEMENT 25
Signalized Intersections

Left-Turn Model Verification and Validation

The procedures for modeling left-turn movements are arguably the most complex analysis procedures of the signalized intersection chapter (Chapter 16) of the HCM2000. Virtually all operational models of signalized intersections, including the HCM2000, account for left-turn adjustments in terms of through-car equivalents. A through-car equivalent is the number of through vehicles that consume the same amount of effective green time traversing the stop line as one left-turning vehicle. Previous research suggests that the values currently used in the 1997 and 2000 HCMs are giving answers very different from other common models, such as the Canadian method and SIDRA.

The HCM2000 provides left-turn adjustment factors for six cases to account for the various lane use types (shared or exclusive) and phasing types (protected, permitted, and protected-plus-permitted) that exist at a signalized intersection. Each case represents a different model. In many cases, the models are not entirely consistent with each other. Analysts comparing alternative treatments have reported that adding a left-turn lane to a situation appears to make matters worse, not better. In addition, the HCM2000 provides different capacity values for a permitted left-turn movement with zero opposing traffic than for a protected (unopposed) left-turn movement, when, intuitively, they should be the same. The problem seems to lie in the fact that the end points of the various models are not necessarily consistent with one another.

Other inconsistencies and weaknesses of the current HCM2000 procedures have been noted and are related to the protected-plus-permitted left-turn model and applications to oversaturated conditions where the accomplishment of left turns is severely restricted.

These known inconsistencies cast doubt onto the validity of the analysis and thus should be identified and corrected.

Research Objectives

The objective of this research is to overcome the deficiencies of the current left-turn models used in capacity analysis.

Research Proposed

The following potential tasks should be considered:

1. Review the current left-turn models used in the HCM2000 for signalized intersection capacity and identify the inconsistencies between the various models and the reason or cause for the inconsistencies.
2. Review the left-turn models used in international applications such as SIDRA and the Canadian method. Compare through equivalency factors produced by HCM2000 for various levels of traffic, geometric, and signal phasing conditions with the international models. Document consistencies and inconsistencies of the theoretical methods and results.
3. For the conditions identified in Items 1 and 2 that produce inconsistencies, collect or obtain field data to evaluate the validity and accuracy of the HCM2000 left-turn models.
4. Evaluate the performance of the HCM2000 left-turn model in oversaturated conditions for a variety of volume, geometric, and phasing conditions.
5. Review the current left-turn equivalency factors used for exclusive and shared left-turn lanes with permitted versus protected phasing. The cases with permitted phasing need to be evaluated for a range of opposing volumes and number of lanes, and validated against field data.
6. Provide recommended improvements to the HCM2000 left-turn models including (*a*) adjustments to model parameters, (*b*) correction factors applied to the model, or (*c*) replacement of the model with a more holistic and consistent model. Evaluate whether a more simplified approach and procedure could be applied that does not compromise the accuracy and precision of the results.

Research Funding and Duration

Estimate of required funding: $200,000
Expected research duration: 2 years

PROBLEM STATEMENT 26
Signalized Intersections

Saturation Flow-Rate Model Verification and Validation

The ability to accurately estimate saturation flow rates is fundamental for determining signalized intersection performance measures such as capacity, delay, and queues. The HCM method of predicting saturation flow rates has been developed incrementally over time. It consists of a multiplicative model that assumes the saturation flow effect of multiple nonideal conditions is the product of all individual nonideal factors. The saturation flow-rate adjustment factors have primarily been developed by isolating a single variable. The combined effects of multiple nonideal factors are largely unknown.

As part of the preparation of the 1985 HCM, field studies were conducted to determine a recommended ideal saturation flow rate for use in the calculation of signalized intersection capacity. Studies conducted after the publication of the 1985 HCM found higher saturation flow rates occurring at intersections even though there was considerable variation in the flow rates. These variations would even occur at the same intersection on differing times of the day or different days. Based on the reported studies conducted by various jurisdictions, in the 1994 update to the HCM, the recommended ideal saturation flow rate for signalized intersections was increased to 1,900 passenger vehicles per lane per hour of green time.

It is commonly accepted that variations in saturation flow exist; however, the degree of variation and the effect that variation has on performance measures is largely unknown. In addition, questions have been raised regarding the appropriateness of a single, nationwide model. To date, there is no substitute for collecting field data to adjust for conditions in smaller or more rural communities that are believed to experience lower saturation flow rates.

Research Objectives

This proposed research has the following objectives:

- Review saturation flow models in use around the world and compare their theoretical framework and adjustment factors with those of the HCM. Identify factors that may be appropriate for inclusion in the HCM model and modifications to the HCM framework that should be considered.
- From literature reviews and field studies, identify key factors that influence saturation flow rates that should be accounted for in saturation flow estimation procedures. These factors may include intersection geometrics, curb lane impedances, congestion levels, intersection environment, geographic location, and driver type.
- Conduct field studies to measure saturation flow rates for the factors identified above in Item 2. Measure for variables both in isolation and in combination with one another.
- Develop a recommended framework for estimating saturation flow based on the results of Items 1 to 3. The framework should include guidance for selecting ideal saturation flow rates and applying adjustment factors. Summaries from the field data collection effort should be provided to give the user an understanding of the degree of variability that can be expected for estimating saturation flow.

- Review the existing HCM procedures for measuring saturation flow, identify deficiencies, and suggest improvements to enhance the procedures and to provide cost-effective methods for obtaining accurate estimates.

Research Funding and Duration

Estimate of required funding: $300,000
Expected research duration: 2 years

PROBLEM STATEMENT 27
Two-Lane Highways

Effects of Operational Treatments on Two-Lane Highway Traffic Operations

Two-lane highways should be analyzed as a facility, including highway sections and intersections. To do this, engineers should be able to analyze the primary types of operational treatments used on these facilities. Auxiliary lanes used as passing, climbing, or downgrade crawl lanes represent some treatments that are currently in use; other treatments include turnouts, shoulder use by slow vehicles, wide cross sections, and turn lanes for entering and exiting traffic. The HCM2000 analyzes some operational treatments such as passing and climbing lanes and, to a limited degree, lane width. Procedures for analyzing more types of operational treatments need to be available for the analysis of two-lane highways, and this is the focus of this problem statement.

Intersection-related operational treatments for signalized and unsignalized intersections and access points can have an effect on two-lane highway operations. Two types of intersection operational treatments are of particular concern. One is additional lanes, either in the form of turn-only lanes or in the form of acceleration lanes. The other is traffic control, which is typically either signal control or stop control.

Additional lanes can help alleviate the adverse effects of turning traffic on two-lane highway operations, but the relationship between turning traffic, lane configuration, and the current two-lane highway measures of effectiveness (i.e., average travel speed and the percentage of time spent following) is poorly understood. The current HCM procedure does allow some adjustment to the average travel speed estimate based on the frequency of access points, but these adjustments were borrowed from the HCM multilane highway procedure as a temporary fix and do not account for the existence of additional lanes for turning vehicles. Current procedures do exist for unsignalized intersections, but they do not include the estimation of turning traffic effects on major-street through traffic.

Intersection traffic control can also affect two-lane highway operations. There are current HCM procedures that do allow one to analyze traffic operations under different types of intersection traffic control, but these existing intersection-related HCM methods are not applicable to two-lane highways for two reasons: (1) they produce results that are inconsistent with the current HCM two-lane highway procedure; and (2) in many cases the two-lane highway cannot be analyzed as an arterial because of the typical large spacing of 3 km or more between intersections where all approaches are controlled.

Two-lane highway operations improve as more passing opportunities are provided. Adding auxiliary lanes, turnouts, or shoulder use can increase passing opportunities. At this time, empirical procedures for analyzing the effects of downgrade crawl lanes, turnouts, and shoulder use are still needed to fully assess the effect of these operational treatments on two-lane highway traffic operations.

Traffic operations are also affected by the cross-section design of two-lane highways. Current methods for analyzing the effects of lane width on two-lane highway traffic operations are very limited and are based on data collected on multilane highways. The current methods could be greatly improved through a more in-depth understanding of driver behavior in the presence of different lane and shoulder widths on two-lane highways.

Research Objectives

The objective of this research is to develop and validate additional methodologies for determining the level of service of two-lane highways, while taking into account the effects of two-lane highway operational treatments. These methodologies could then be incorporated into the HCM2000 methodology, allowing for a more consistent accurate analysis of entire two-lane highway facilities, including the intersections.

Effects of these operational treatments may vary depending on the traffic and geometric conditions. It is important that the research be conducted so that these effects are understood across the typical range of conditions in which the treatments are applied and that the methods for analyzing these treatments are compatible with the current HCM methodology. To do this, the following tasks need to be completed:

- Assess the current capabilities and limitations of the HCM2000 two-lane highway, signalized intersection, unsignalized intersection, and urban street methodologies for modeling operational treatments.
- Identify sites where traffic observations can be made.
- Determine a data collection methodology.
- Collect field data at the identified sights.
- Identify a simulation package that can be used to model two-lane highway and intersection operations and the operational treatments that are being investigated. This will likely be TWOPAS after the capability to model intersection operations has been added. The modified TWOPAS software is currently in the testing stages. However, a simulation package that models all of the operational treatments proposed in the problem statement may not be available, in which case the research will be based primarily on field data.
- Calibrate and validate the simulation model.
- Determine a strategy for incorporating a methodology for analyzing the said operational treatments into the two-lane highway methodology.
- Develop and validate the methodologies for analyzing the operational treatments.

Research Funding and Duration

Estimate of required funding: $800,000
Expected research duration: 4 years

PROBLEM STATEMENT 28
Two-Lane Highways

Traffic Operational Analysis Methods for Additional Two-Lane Highway Types

Two-lane highway facilities around the United States serve a variety of functions and operate under very different traffic conditions, with varying speed–flow relationships. These include facilities as diverse as two-lane highways with multiple access points and lower speeds, suburban two-lane highways with relatively high speeds and isolated signalized intersections, and rural scenic two-lane highways in mountainous terrain or along beaches.

Application of the HCM2000 two-lane highway operational analysis methodology in the field has shown that the current categorization of two-lane highways in two classes may not adequately address the variety of two-lane highways now existing in the field. The level of service thresholds and capacities currently reported in the HCM2000 may not be appropriate for all different types of two-lane highways. Furthermore, there is a need to make the HCM2000 technique multimodal in structure by including bicycle level of service analysis as well as truck, bus, and public transportation issues (such as bus-stop considerations). There is also a need to assess and categorize all different types of two-lane highways currently existing in the United States, to obtain field data from a wide variety of two-lane highway facilities, and to validate and adjust as necessary the HCM2000 methodology. For newly identified classes of two-lane highways, appropriate service measures and thresholds should be defined. Additionally, an evaluation of the applicability of the service measures and thresholds currently recommended in the HCM2000 for existing classes of two-lane highways should be performed.

The final product of this project will primarily consist of appropriate revisions and additions to Chapters 12 and 20 of the HCM2000 to incorporate the typology developed and to provide appropriate methods of analysis for each type of two-lane highway facility.

Research Objectives

The objective of the proposed project is to create a typology of two-lane highway facilities around the United States and to develop appropriate methods of traffic operational analysis for those that existing methods do not address.

Research Proposed

The proposed project will

1. Collect field data to develop an inventory and characteristics of two-lane highway facilities around the United States;
2. On the basis of these data, create a typology of two-lane highways, considering factors such as urban, suburban, and rural environments; access points; and operating speeds through the section;
3. Assess the applicability of the HCM2000 methodology (and other existing methods) to each of the identified two-lane highway types;
4. Recommend or develop appropriate methods of analysis for each type of two-lane highway, considering multimodal issues and traveler perceptions of quality of service and bicycle level of service; and

5. Develop default values for each type of two-lane highway for planning purposes. The proposed research should be coordinated with the research recommended in Problem Statement 30, which will address capacity and quality of service procedures for generally uninterrupted flow facilities, including both two-lane and multilane facilities.

Research Funding and Duration

Estimate of required funding: $600,000
Expected research duration: 4 years

PROBLEM STATEMENT 29
Two-Lane Highways

Capacity and Quality of Service Analyses for Generally Uninterrupted Flow Facilities

A significant gap in the HCM2000 is the facility analysis of uninterrupted flow highways. The HCM contains procedural analysis techniques for two-lane and multilane segments, but it does not contain a technique to analyze the capacity and level of service for the facility as a whole. The HCM also contains facility analysis techniques for other roadway types (i.e., interrupted flow urban streets and freeways) but not for these generally uninterrupted flow facilities. Given that the HCM is nationally accepted as the primary source on highway capacity and quality of service, not having a technical technique that addresses many of the nation's highways is a major limitation.

Most of the research on two-lane and multilane uninterrupted flow segments was conducted in rural areas. Although not predominant, numerous situations exist in developed areas (e.g., small towns, causeways in metropolitan areas) in which capacity and quality of service analysis techniques are needed.

In most rural situations, capacity analysis is relatively meaningless because capacity is nearly never met. Capacity for highways containing these segments is usually caused by some isolated signalized intersections or other control conditions related to more developed areas. These factors should be considered in analyses of uninterrupted flow facilities.

In using existing uninterrupted flow two-lane highway segment techniques, states get poor or even failing level of service results in developed situations. This often leads to costly roadway expansion and excessive highway widenings in small communities in order to meet level of service standards. By having more appropriate level of service measures for these types of facilities, states can better allocate their scarce resources.

No research has been performed to determine how actual drivers perceive the quality of service provided by these highways. Level of service thresholds have been set by knowledgeable professionals, rather than being based on driver perceptions. In addition, no research has been conducted on how bicyclists perceive levels of service on the segments or these facilities as a whole.

Research Objectives

The objective of this research is to develop nationally accepted capacity and quality of service techniques for generally uninterrupted-flow highway facilities with the intent that the research would lead to development of a new chapter in the HCM.

Research Proposed

The following potential tasks should be considered:

1. For generally uninterrupted-flow facilities, collect quality of service data in rural and developed areas for the automobile and bicycle modes.
2. Collect field data and determine default values for urban and developed situations on the capacity of generally uninterrupted-flow facilities.
3. Create a typology of generally uninterrupted-flow facilities considering factors such as development levels (e.g., rural undeveloped, rural developed, suburban), roadway characteristics (e.g., number of lanes, access point density, free flow speed, terrain), roadway analysis lengths and termini (e.g., isolated signalized intersections), and purpose (e.g., through movement, local traffic).
4. Assess the applicability of HCM2000 two-lane segment, multilane segment, signalized intersection, and unsignalized intersection methodologies for use in the development of a generally uninterrupted-flow facility analysis.
5. Develop an operational level analytical methodology.
6. Using the operational methodology, develop planning and preliminary engineering applications based on default values and/or simplifying assumptions.
7. Determine appropriate service measures or a way of combining multiple service measures encompassing various segments (e.g., two-lane segment, multilane segment, signalized intersection influence area).
8. Coordinate with the HCQS Committee that oversees the HCM for implementation of results.
9. Develop technical reports of sufficient detail so that project results can be relatively easily incorporated into the HCM.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2 years

PROBLEM STATEMENT 30
Unsignalized Intersections

Assessment of Simulation Tools for Unsignalized Intersections

As traffic congestion increases and computing methods become more sophisticated, simulation models are becoming more widely used to evaluate congested roadway facilities and complex interactions between conflicting traffic movements. This research is intended to increase the level of knowledge regarding simulation techniques at two-way stop-controlled (TWSC) intersections, all-way stop-controlled (AWSC) intersections, and roundabouts. It will specifically address the following problems:

- Traffic engineers in the United States do not have a well-known simulation model that can be used to analyze isolated AWSC, TWSC, and roundabout intersections. Are there simulation tools available in the United States or elsewhere that can be used for this purpose? If so, what are each model's data needs, strengths, and weaknesses? How do their results compare with the HCM and available data collected at unsignalized intersections?
- Many simulation models are available to analyze complex networks of signalized intersections. Most of these models include the ability to include unsignalized intersections within the networks. However, the focus of these models is the interaction between traffic signals, not the operations of unsignalized intersections. Do these models accurately portray conditions at unsignalized intersections? How do their results compare with the HCM and available data collected at unsignalized intersections? Are there any recommended improvements that could be made based on analysis of the models or based on the models available for isolated unsignalized intersection analysis?

Research Objectives

The objective of this research is to conduct a literature search and limited investigation into the available simulation models that can to accommodate unsignalized TWSC, AWSC, and roundabout intersections.

The first part of the study will focus on isolated intersection analysis. A literature search will be conducted to determine whether there are any simulation models in the United States or elsewhere that are focused on the isolated analysis of unsignalized intersections. On the basis of this search, up to three selected simulation models will be subjected to more detailed study. A set of sample problems will be developed, and the results of the simulation models will be compared with the results of the HCM and available field data. The sample problems will be set up with existing field data in mind; no new field data will be collected. Based on the results of this analysis, a summary of each model will be written, including its strengths and weaknesses and comparisons to the HCM and field data.

The second part of the study will focus on networks of intersections. A literature search will be conducted to determine the six most widely used network simulation models in the United States that are capable of TWSC, AWSC, and roundabout intersection analysis. A set of sample problems will be developed, and the results of the simulation models will be compared with the results of the HCM and available field data. The sample problems will be set up with existing field data in mind; no new field data will be collected for the study. Based on the results of this analysis, a summary of each model will be written, including its strengths and weaknesses and comparisons to the HCM and field data.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature search to determine up to three simulation models that focus on isolated analysis of TWSC, AWSC, and roundabout intersection analysis and the six most widely used network analysis simulation models in the United States that are capable of TWSC, AWSC, and roundabout intersection analysis.
2. Conduct a literature search to gather existing field data collected at TWSC and AWSC intersections.
3. Develop an experimental design to provide comparisons of the simulation models to the HCM and field data.
4. Prepare and submit an interim report containing the literature search and the experimental design.
5. Analyze the simulation models as described in the approved experimental plan.
6. Provide a summary of the results of the analysis.
7. Document the research effort and findings in a final report.

Research Funding and Duration

Estimate of required funding: $600,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 31

Unsignalized Intersections

Development of Traveler-Based Level of Service Methodologies for Unsignalized Intersections

Traffic engineers currently evaluate the performance of unsignalized intersections using the methods of the HCM and/or traffic signal warrants contained in the *Manual on Uniform Traffic Control Devices* (MUTCD). These methodologies are based on performance measures such as vehicle traffic, pedestrian traffic, delay, safety, etc., and recommend changes in traffic control when these measures experience a significant change. One piece of information that is missing in the analysis of unsignalized intersections is the reflection of traveler perceptions of operational performance at various types of intersection control. The proposed study would seek to gain insight into the factors that most influence traveler-perceived satisfaction with unsignalized intersection performance. It would also seek to determine thresholds of acceptable performance associated with these factors.

Research Objectives

The objective of this proposed research is to provide agencies with the tools necessary to compare the performance of the following intersection control types from a traveler perspective:

- Two-way stop control,
- All-way stop control, and
- Roundabouts.

This will provide traffic engineers and decision makers with the tools necessary to incorporate customer satisfaction measures into the current analysis tools used to make investment decisions.

The study's objectives will be accomplished through the following:

- Identifying significant factors within the right-of-way that can be influenced by the transportation community that affect driver perception of operational performance of unsignalized intersections, and
- Modeling the expected level of performance provided to the traveler by each type of intersection control and across intersection control types.

This will be accomplished using data collection techniques that place the traveler as close to the subject intersection types as possible, such as in-field, video laboratory, and/or focus groups with video laboratory. The study should be conducted in two phases to allow for the qualitative exploration necessary: first, to identify factors most important to drivers traversing unsignalized intersections and, second, to quantify the weight of each factor on the overall assessed level of performance from a traveler perspective.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature search and state-of-the-practice review. Prepare a synthesis on the topic.
2. Develop an experimental design to study travelers' perceptions of performance at unsignalized intersections.
3. Prepare and submit an interim report containing the literature search, state-of-the-practice review, and the experimental design.
4. Analyze the data as described in the approved experimental plan.
5. Recommend methodologies to estimate the performance of unsignalized intersection performance from a driver perspective and supporting text to be incorporated into future editions of the HCM and MUTCD.
6. Prepare a computational engine in an electronic spreadsheet or other format that can be used to test the updated HCM procedures.
7. Document the research effort and findings in a final report.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2 years

PROBLEM STATEMENT 32
Unsignalized Intersections

Effect of Traffic Demand on Gap Acceptance at Two-Way Stop-Controlled Intersections

The HCM methodologies for unsignalized intersections include the use of constant gap acceptance periods for conflicted movements regardless of the traffic demand at the intersection. It is hypothesized that driver behavior does not follow a constant gap acceptance model and that, in fact, gap acceptance varies based on traffic demand and time spent waiting in queue. It is also hypothesized that driver perception of quality of service and system reliability is affected by travel demand. The proposed study would seek to identify the relationship between traffic demand and gap acceptance at unsignalized intersections as well as the effect on driver perception of quality of service and reliability. If a relationship between traffic demand and/or time spent in queue can be established and if this effect can be estimated in the unsignalized intersection capacity procedure, a more accurate procedure will result.

Research Objectives

The objective of this research is to collect new field data at TWSC intersections and to use those data to determine the relationships between traffic demand and time spent in queue on gap acceptance. The data should be collected over as wide a geographic area as possible in order to include different regions of the United States. It should be collected over a range of intersection use but should concentrate on intersections that are near capacity.

The data collected in this study should be well documented so that it can be used in future research efforts. The results of the field data will be compared with the results obtained with the current HCM procedures. Recommendations will be made to revise the current HCM procedures to better match the field data collected during this study.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature search to gain an understanding of the analysis leading up to the current HCM procedures and to summarize methodologies used to determine gap acceptance.
2. Develop a data collection plan that will provide for new field data at TWSC intersections to determine the effects of traffic demand and time spent in queue on gap acceptance. The data should reflect a broad representation of different regions of the United States.
3. Prepare and submit an interim report containing the literature search and the data collection plan.
4. Collect the field data and document them in a format that can be used in future research efforts.
5. Compare the results of the field data with the results of the current HCM procedures and recommend revisions to the HCM.
6. Prepare a computational engine in an electronic spreadsheet or other tool that can be used to test the revised HCM procedures.

7. Prepare and submit another interim report containing the results of the data collection and the recommendations to revise the HCM procedures.
8. Coordinate with the HCQS Committee to ensure consistency with the committee's work.
9. Provide a summary of the results of the analysis.
10. Document the research effort and findings in a final report. Include specific changes to the text of the HCM in order to implement the changes recommended in this research.

Research Funding and Duration

Estimate of required funding: $300,000
Expected research duration: 2 years

PROBLEM STATEMENT 33
Unsignalized Intersections

Enhancement and Calibration of the Two-Way Stop-Controlled Intersection Capacity Analysis Procedure

The TWSC intersection capacity analysis procedure is one of the most widely used procedures in the HCM. Despite the high level of interest in this procedure, it has several characteristics that limit its usefulness. This research will provide for enhancement and calibration of this popular procedure.

The TWSC intersection procedure in the HCM2000 lacks the ability to analyze TWSC intersections along six-lane streets. An additional limitation of the procedure is that it contains three relatively new features that were included based on requests from users to analyze intersections with special characteristics. These relatively new features include upstream signal effects, two-stage gap acceptance, and pedestrian effects. While methodologies have been developed to include these characteristics, they were developed based on limited data. Use of these methodologies over time has revealed significant concerns from users of the HCM regarding the accuracy of these new methodologies. Further study is needed to add the ability to analyze six-lane streets and to increase the accuracy of the relatively new features of the TWSC procedure.

Research Objectives

The objective of this research is to collect new field data at TWSC intersections and to use that data to calibrate and enhance the existing HCM procedures related to six-lane streets, upstream signal effects, two stage gap acceptance, and pedestrian effects. The data should be collected over as wide a geographic area as possible in order to include different regions of the United States. It should be collected over a range of intersection utilization but should concentrate on intersections that are near capacity.

In order to fulfill the research objective, it will be necessary to select separate groups of intersections that either are located along six-lane streets or have significant upstream signal effects, two stage gap acceptance, or heavy pedestrian usage. The data should be well documented so that it can be utilized in future research efforts. The results of the field data will be compared with the results obtained with the current HCM procedures. Recommendations will be made to revise the current HCM procedures to better match the field data collected during this study.

At the beginning of the study, a literature search will be conducted to obtain an understanding of previous research efforts that led to the development of the current HCM procedures. In addition, the literature search will seek to summarize methodologies used in other countries that may be applicable in enhancing the HCM procedures.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature search to gain an understanding of the analysis leading up to the current HCM procedures and to summarize methodologies used in other countries to analyze six-lane major streets, upstream signal effects, two stage gap acceptance, and pedestrian effects at TWSC intersections.
2. Develop a data collection plan that will provide for new field data at TWSC intersections with six-lane major streets, significant upstream signal effects, two-stage gap acceptance, and a high level of pedestrian usage. The data should reflect a broad representation of different regions of the United States.
3. Prepare and submit an interim report containing the literature search and the data collection plan.
4. Collect the field data and document them in a format that can be used in future research efforts.
5. Compare the results of the field data with the results of the current HCM procedures and recommend revisions to the HCM.
6. Prepare a computational engine in electronic spreadsheet or other format that can be used to test the revised HCM procedures.
7. Prepare and submit another interim report containing the results of the data collection and the recommendations to revise the HCM procedures.
8. Coordinate with the HCQS Committee to ensure consistency with the committee's work.
9. Provide a summary of the results of the analysis.
10. Document the research effort and findings in a final report. Include specific changes to the text of the HCM in order to implement the changes recommended in this research.

Research Funding and Duration

Estimate of funding required: $700,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 34
Unsignalized Intersections

Unsignalized Movements at Signalized Intersections

Most traffic movements at signalized intersections are tightly controlled by the traffic signal's operation. This research will address three types of traffic movements at signalized intersections that are heavily influenced by driver behavior:

- Right turn controlled by a yield sign,
- Right turn on red, and
- Permitted left turn.

These types of movements are addressed to some degree in the HCM2000. Permitted left turns are addressed, but there are concerns about the accuracy of the methodology. Right turn on red analysis is addressed, but only to the extent that the right turn on red vehicles are deleted from the calculation. There is no methodology provided to calculate right turns on red, and the value must be specified by the user. Right turns controlled by a yield sign are not addressed at all. In addition, there are questions regarding whether the methodologies for handling these traffic movements at signalized intersections should be consistent with similar methodologies for unsignalized intersections.

Research Objectives

The objective of this research is to collect new field data on unsignalized movements at signalized intersections and to use those data to calibrate and enhance the existing HCM procedures for right turns controlled by a yield sign, right turns on red, and permitted left turns. The data should be collected over as wide a geographic area as possible in order to include different regions of the United States. It should also be collected over a range of intersection use.

The data collected during this research should be well documented so that it can be used in future research. The results of the field data will be compared with the results obtained with the current HCM procedures. Recommendations will be made to revise the current HCM procedures to better match the field data collected during this study. In addition, a comparison of the current HCM procedures for signalized and unsignalized intersections should be compared to determine whether the procedures should be consistent for the traffic movements that are the subject of this research.

Research Proposed

The following potential tasks should be considered:

1. Conduct a literature search to gain an understanding of the analysis leading up to the current HCM procedures and to summarize methodologies used in other countries to analyze right turns controlled by a yield sign, right turns on red, and permitted left turns at signalized intersections.

2. Develop a data collection plan that will provide for new field data at signalized intersections. The data should reflect a broad representation of different regions of the United States.
3. Prepare and submit an interim report containing the literature search and the data collection plan.
4. Collect the field data and document it in a format that can be used in future research efforts.
5. Compare the results of the field data with the results of the current HCM procedures and recommend revisions to the HCM.
6. Prepare a computational engine in electronic spreadsheet or other format that can be used to test the revised HCM procedures.
7. Prepare and submit another interim report containing the results of the data collection and the recommendations to revise the HCM procedures.
8. Coordinate with the HCQS Committee to ensure consistency with the committee's work.
9. Provide a summary of the results of the analysis.
10. Document the research effort and findings in a final report. Include specific changes to the text of the HCM in order to implement the changes recommended in this research.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 35
Urban Streets

Modeling Procedure for Congested Arterial Facilities

Performance of urban arterial streets strongly affects the overall costs and travelers' perceptions of transportation in the area. The ability to evaluate arterial streets is a critical condition of effective traffic management and control in urban areas. The HCM provides a procedure for evaluating urban arterial streets. This procedure aggregates outcomes from the analysis of signalized intersections to calculate the average arterial travel speed and the level of service. This approach, although appropriate for noncongested arterial streets, cannot properly deal with arterial congestion. Metering of arterial traffic by signals and queues reaching upstream intersections are not considered. The existing HCM procedure may incorrectly calculate travel speed and other measures of arterial performance for congested traffic.

Research Objectives

The objective of this research is to improve the HCM model of arterial streets to adequately describe congested traffic. This should be accomplished by incorporating the effect of traffic metering and traffic blockage by long downstream queues. The new procedure will include the effect of signal progression. The new procedure will follow the concepts defined in the HCM. It will require input and produce outcome consistent with the HCM procedures for signalized and unsignalized intersections.

As arterial operations under congestion can last for a considerable time, the new procedure will be able to use traffic volumes given in multiple consecutive intervals. This research should, to the extent possible, use the findings of previous research on the effect of metering, filtering, and spillback on urban arterial operation. The resulting procedure will be tested with computer simulation and validated with field data.

Research Funding and Duration

Estimate of required funding: $400,000
Expected research duration: 2 years

PROBLEM STATEMENT 36
Urban Streets

Operational and Capacity Effects of Unsignalized Access on Urban Streets

Although a great deal is known about signalized intersections and their effects on through traffic, much less is known about the effects of access points on the operation of urban streets between signalized intersections. The impacts on through-traffic speed can be profound when there is a high frequency of closely spaced access points (i.e., driveways and unsignalized public street intersections). These effects, of course, become more pronounced when there are substantial volumes in and out of many of the access points.

A limited number of case studies have documented degradation in travel speed and reductions in capacity for very specific driveway and roadway configurations. Currently, however, there is no procedure that can effectively predict the impact of a wide variety of driveway and roadway configurations on the average travel speed of through traffic.

The presence of access points along a roadway is assumed to have a frictional impact on through traffic. That is, average travel speeds will be marginally lower on roadways where access points are present, even if there is no ingress and egress activity at the points. The reduction in speeds becomes more pronounced as the level of ingress and egress activity at the access points increases. Simply stated, increased activity impedes more of the through traffic, forcing it to slow down and/or change lanes. The extent to which through traffic is impeded is a function of (1) the movements allowed in and out of the driveway, (2) the volume of these movements and the through traffic, (3) the design of the driveway, and (4) the cross section of the roadway. While it is valuable to be able to quantify the impacts of individual access points, it is equally important to study the synergistic effects of multiple driveways as a function of their frequency and spacing.

Research Objectives

The objective of this study is to establish a procedure that can be used to evaluate the operational effects of one or more access points along an urban street segment. The objective would be accomplished by addressing the problems described in the research problem statement. This would include addressing the effect of access frequency on through-vehicle speed, through-lane use, and platoon structure. The evaluation procedure must be sensitive to the level of activity at individual access points and the interdependencies of multiple access points. Consequently, it should be able to quantify impacts for a wide variety of driveway configurations over a single block or a series of blocks. The goal is to provide actual average travel speeds for through traffic that are representative of the real world. This will allow practitioners not only to determine more accurately the levels of service for urban streets but also to predict the impacts associated with the proposed design and location of access points.

Development of the desired procedure will entail extensive field data collection and analysis that will complement simulation activities. Simulation will be used to model the wide variety of design, spacing, and movement volume issues discussed above.

Research Funding and Duration

Estimate of required funding: $350,000
Expected research duration: 2.5 years

PROBLEM STATEMENT 37
Urban Streets

Level of Service for Arterial Weaving Segments

Weaving activity occurs to some degree on almost all arterial street segments. The extent of arterial weaving activity is directly related to the number of vehicles that enter or exit the segment via a turn maneuver. The negative effects of weaving activity on traffic speed are well documented in the context of freeway weaving areas. Weaving on an arterial segment also tends to reduce traffic speeds; however, very little is known about the magnitude of the effect. The existing procedures for freeway segments are not likely to be applicable to arterial street segments because of their differences in traffic control and driver behavior. The freeway section represents uninterrupted flow with merging control for entering vehicles. In contrast, the arterial segment is often regulated by upstream and downstream signals and may use no control, yield, stop, or signal control to regulate both the entry and the exit maneuver. Arterial weaving capacity is significantly affected by the gaps introduced by the upstream signal and the distance available for weaving (which varies with the queue length at the downstream signal).

Arterial weaving is most problematic on street segments associated with large turning volumes. Such volumes are often found near interchanges. For example, intensive weaving activity is often found on the segment between the interchange off-ramp terminal and an adjacent signalized intersection. It is also found on frontage road segments between the freeway off-ramp and the frontage-road and cross-street intersection.

It is possible that the current service measures for freeway weaving are not appropriate for arterial weaving. Therefore, this study should seek to gain insight from the traveler population to identify appropriate measures and thresholds of performance.

Research Objectives

The objective of this research is to develop a deterministic procedure for evaluating the level of service in weaving areas on arterial street segments. This includes the identification from a traveler's perspective, of appropriate performance measures and thresholds for the evaluation of level of service and the development of a quantitative methodology for the estimation of those measures.

Research Proposed

The research should define one or more service measures suitable to weaving area performance evaluation. The model should be sufficiently general as to be applicable to the wide range of weaving segment control modes, weave maneuvers (e.g., entry by right turn with exit by left turn, entry as through with exit by right turn, etc.), entry angles, acceleration distance, arterial lanes, and weaving distance. Simulation can be used to develop and calibrate the proposed procedure; however, field data should be used to validate the procedure. The field data should reflect conditions throughout the United States.

Research Funding and Duration

Estimate of required funding: $600,000
Expected research duration: 3.5 years

PROBLEM STATEMENT 38
Urban Streets

Capacity and Quality of Service Analysis of Urban Local Streets

An intent of the HCM2000 was to address all major highway facility types from intersections to networks. Although the HCM2000 has a chapter on urban streets, it only addresses arterials in which average travel speed is used to address levels of service. The vast majority of urban streets, however, are not arterials; they are local streets. It is likely that drivers on local streets do not consider average travel speed nearly as important as they do on arterials. Furthermore, pedestrian, bicycle and transit movements and perception of levels of service of these modes are likely to be different than on arterials.

Research Objectives

The objective of this research is to develop a procedure for estimating the capacity and level of service thresholds for the automobile, pedestrian, bicycle, and transit modes on urban local streets. It is anticipated this research will lead to a new chapter in the HCM.

Research Proposed

Performance measures for the automobile, pedestrian, bicycle and transit modes are to be developed from a traveler perspective. Developed analysis techniques should be multimodal in structure, in particular with respect for the interaction among the modes. A multimodal approach does not imply a single level of service for the urban local street. Analysis techniques may be tested through field studies, simulations, focus groups, written surveys, or other means. The following potential tasks should be considered.

1. Develop a level of service technique for the pedestrian mode. Evaluate and integrate leading pedestrian level of service methodologies from FDOT, the pedestrian level of service model developed by SCI, the HCM, and others.
2. Update the LOS techniques for the bicycle mode. Evaluate and integrate leading bicycle level of service methodologies from FDOT, FHWA's Bicycle Compatibility Index developed by the University of North Carolina, the Bicycle Level of Service Model developed by SCI, the HCM, and others.
3. Review level of service techniques for the automobile and truck modes from a multimodal perspective. Review urban streets chapters of the HCM with the intent of expansion to a multimodal chapter. Identify key factors needed for and affected by multimodal analysis. Identify any changes needed in the methodologies to accommodate multimodal analysis.
4. Reevaluate and, as appropriate, update level of service techniques for the scheduled fixed route bus mode. Evaluate and integrate the *Transit Capacity and Quality of Service Manual,* the HCM, FDOT's transit level of service and multimodal level of service program, and others.
5. Develop a framework for simultaneous multimodal arterial analysis. Evaluate the FDOT's multimodal level of service methodology; the Traffic System Performance Evaluation System of Portland, Oregon; and others to determine the best framework for multimodal analysis.
6. Validate results. Query a statistically valid sample of roadway users in at least three areas of the United States. Design and conduct statistically valid studies of users to validate the multimodal level of service framework in at least three areas of the United States. SCI's Pedestrian and Bicycle LOS Models and the University of South Florida's Pedestrian Midblock Crossing Difficulty project provide good examples of validation techniques that can be expanded to encompass each of the modes in each of the study locations.
7. Document the methodology in the next updates of the HCM and the *Transit Capacity and Quality of Service Manual*.

Research Funding and Duration

Estimate of funding required: $400,000
Expected research duration: 2.5 years

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