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A PROGRAM OF RESEARCH IN HIGHWAY CAPACITY

Operation, Safety, and Maintenance of Transportation Facilities

Adolf D. May, Chair A3A10

Rahmi Akcelik
Ulrich Brannolte
Ken G. Courage
R.E. DeArazoza
Daniel B. Fambro
Douglas W. Harwood
Paul Jovanis
Wayne K. Kittelson
Michael D. Kyte
Herbert S. Levinson
John F. Morrall
Barbara K. Ostrom
Ronald C. Pfefer
James L. Powell
William R. Reilly
Carlton C. Robinson
Roger P. Roess
Negui M. Rouphail
Ronald C. Sonntag
Henri L. Stembord
Stan Teply
Pierre Yves Texier
Thomas Urbanik, II
Mark R. Virkler
Robert H. Wortman
John D. Zegeer

Committee A3A10
Task Force on Research
Nagui M. Rouphail, Chairman
Paul Jovanis
Joel P. Leisch

Subscriber Category
IVA highway operations, capacity and traffic control

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

PREFACE

This document sets forth a national research program on highway capacity. It is the product of extensive deliberations by the members of the Highway Capacity and Quality of Service Committee (HCQS) of the Transportation Research Board, of the Highway Capacity Manual (HCM) users' feedback gathered in a series of open forums and, of input from the individual members of the Task Force charged with this assignment.

The program recommends the conduct of twenty-one separate research studies as a means to address deficiencies in the present Manual and upgrade future editions. The total cost of the program is $3.55 million over the next six years. The first study listed in this program is already under contract by NCHRP at a cost of $400,000. The program cost figure includes direct research expenditures, software development, and the production of draft chapters. In addition to the $3.55 million program, $100-$150K will be required to develop the final version as well as the introductory Chapters 1 and 2.

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CHAPTER 1 INTRODUCTION

Background

The Transportation Research Board Committee on Highway Capacity and Quality of Service has historically had a unique position in the transportation research community. It has been responsible for the development, review and approval of three editions of the U.S. Highway Capacity Manual (known throughout the world as the HCM). The original Manual, published in 1950, was the first to quantify in a rigorous way the concept of facility capacity. The second Manual, published in 1965, was the first to define the concept of level of service, a concept that has been the cornerstone of most transportation planning, design and operations studies since 1965. The most recent Manual, published in 1985, contained significant revisions to many chapters most notably signalized and unsignalized intersections and arterials. It also contained new chapters on transit, bicycles and pedestrians.

The 1985 Manual is also significant because it is the first edition that has had micro-computer software developed to facilitate analysis. The Federal Highway Administration (FHWA) contracted for an official translation of the Manual and numerous versions and options are available through the private sector and the McTrans Micro Computer Center at the University of Florida. TRB has printed 12,000 copies of the hard copy version. There is no question of the Manual's popularity. It has always been a best seller and continues to be the document which transportation analysts around the world rely on for state of the art methods.

Program Objectives

The 1985 Manual has been available for 5 years and micro computer software for nearly as long. There is a need to lay out a plan of research so the next version of the Manual can be produced at the proper time, about the year 2000. Formal workshops have been conducted, cosponsored by the Institute of Transportation Engineers. Additionally, numerous professional short courses have been conducted, instructing engineers on the use of the methods and soliciting feedback regarding user experiences. We are at the point where we can identify areas of future research, both from a perspective of the research and user communities.

Given time lags to arrive at the point of completed research products, now is the time to describe a plan of capacity research for the next 10 years that will culminate in a new manual by the year 2000. The remainder of this document describes such a research plan. In addition, it is important to review additional forces currently shaping transportation research. The capacity research program obviously exists within this larger context and is shaped by many of the same forces. The next section describes these forces in overview and articulates their effects on, and relationship to, the proposed capacity research program.

External Events Influencing the Capacity Research Program

Technological forces are changing the way transportation services are provided. Intelligent Vehicle and Highway Systems (IVHS) are quickly becoming the focus of transportation research in the next decade and beyond. At the same time, continued improvements in computer speed, memory and graphics displays are providing greatly enhanced analysis capability. More recently, with passage of the new Federal Clean Air Act, there will be even more scrutiny of major transportation investments. We must develop improved modeling capabilities to more accurately assess the implications of capacity and level of service improvements.

While the national IVHS program is in its infancy, it is already commanding substantial attention and resources. It is critical that the next HCM explicitly deal with relevant aspects of IVHS. Two examples are illustrative of the types of issues that can arise. Because signalized intersections are frequently the bottlenecks in a street system, one aspect of IVHS is likely to deal with methods to increase intersection approach capacity. These may include systems that re-route turning traffic away from congested intersections. As in-vehicle route guidance and navigation systems are likely to be among the first deployed IVHS systems, their implications for capacity expansion need to be better understood and modelled. Enhanced cruise control systems could allow vehicles to follow at more uniform and shorter headways, improving both capacity and level of service. While the technological details of the systems are not within the purview of the manual, their implications should be.

While technology is allowing us to consider actively the deployment of new innovative transportation systems, it is also providing enhanced power to analyze transportation investments. The emerging generation of micro computers will allow significantly more complex computations than were possible with paper and pencil methods. The 1985 Manual was primarily developed as a manual technique that was later applied to computer code. We now have the opportunity to develop methods that are primarily developed for computer use. These would include the possibility of using existing simulation models (such as the FHWA TRAF series) to analyze capacity and level of service. The point here is not to advocate one method at the exclusion of others; the fact is that the next generation of computer systems will allow the researcher many more options to apply to a problem. Because a more complete model of traffic

systems should evolve, it is reasonable to expect that accuracy will improve substantially.

Organization of this Document

In its midyear meeting in June 1989, the HCQS Committee prepared a preliminary list of problem areas to remedy the remaining deficiencies in the 1985 HCM. A Task Force was appointed to organize these statements in the context of an overall program for capacity research. This draft represents a concerted effort in that direction. This document is organized as follows. First, a breakdown of studies and funding requested by Chapter (in 1985 HCM) is given. Next, a detailed implementation plan is proposed, which includes the identification of project prioritics, a time schedule for completing the research and a plan for the dissemination of the results. Research problem statements are categorized by the two classifications of traffic flow facilities given in the 1985 HCM: uninterrupted flow facilities (Chapters 3-8) and interrupted flow facilities (Chapters 9-14). For each section, a summary discussion of the proposed research is given, followed by individual project statements. At the conclusion of each section, a listing of proposed projects and funding levels is presented.

CHAPTER 2 PROGRAM HIGHLIGHTS

Key Statistics

- Total number of studies[1]: 21,
- Number of new studies proposed: 20,
- Total funding[1]: $3.55 million,
- Total new funding requested: $3.15 million,
- Time horizon to complete work: 6 years,
- Proposed starting date: July 1991,
- Proposed completion date: June 1997, and
- Breakdown by chapter in 85 HCM: see Exhibits I and II.

Project Listing

Project Number, Title

1. Capacity and LOS at Ramp/Freeway Junctions[2]
2. Coordination of Freeway Research
3. Survey of High Volume Locations
4. Survey of Two-Lane Highways Problems
5. Improved Simulation of Two-lane Highways
6. Two Lane Highways Capacity and LOS Procedures
7. Revision of Planning Method, Signalized Intersections
8. Revision of Operational Method, Signalized Intersections
9. Operational Analysis of Exclusive LT Lanes
10. Capacity Analysis of Actuated Traffic Controllers
11. New Procedures for Capacity and LOS, Unsignal.Intersections
12. Arterial Traffic Operations
13. Relating Arterial Time/Space Diagrams to LOS
14. Arterial Chapter Coordination with other Chapters
15. Bus Flows on Multilane Streets
16. Light Rail Transit Capacity on City Streets
17. Effect of Door Width on Transit Service and Capacity
18. Revisions to Chapter 12: Transit
19. Revision of HCM Chapter 13: Pedestrians
20. Uninterrupted Bicycle Flow Characteristics
21. Revision of Highway Capacity Manual Chapter 14: Bicycles

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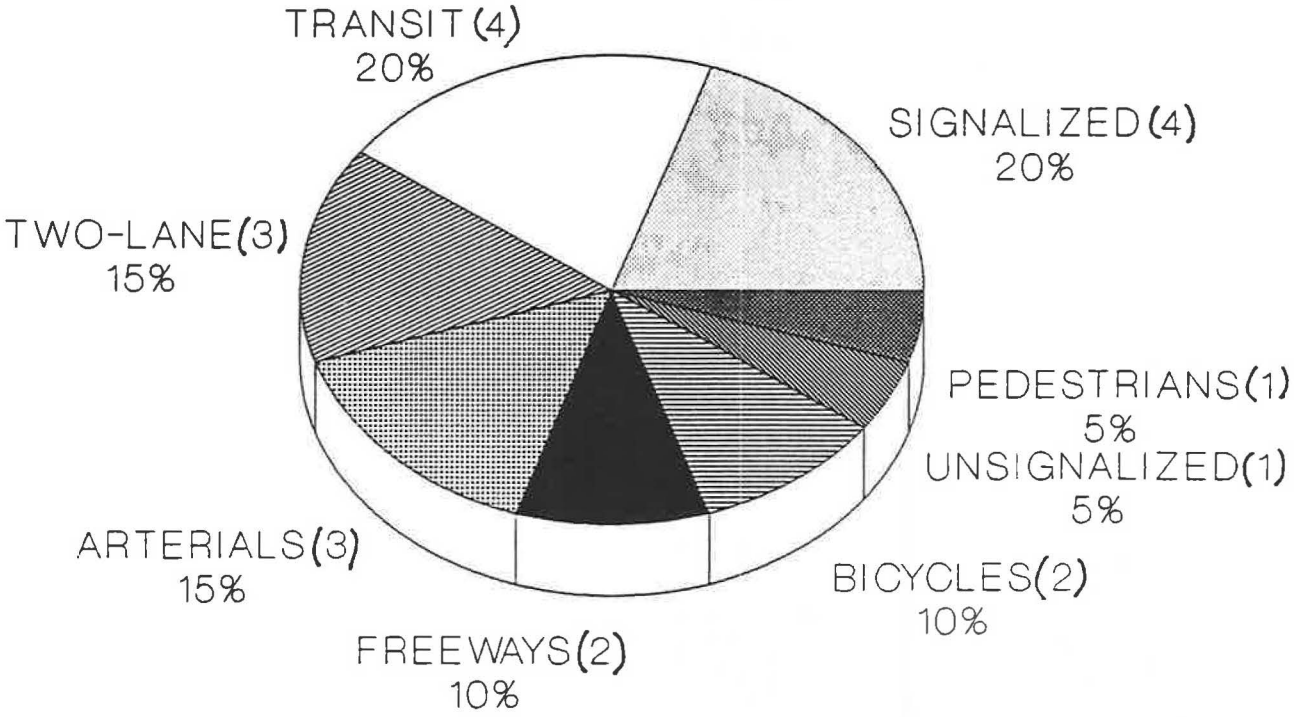
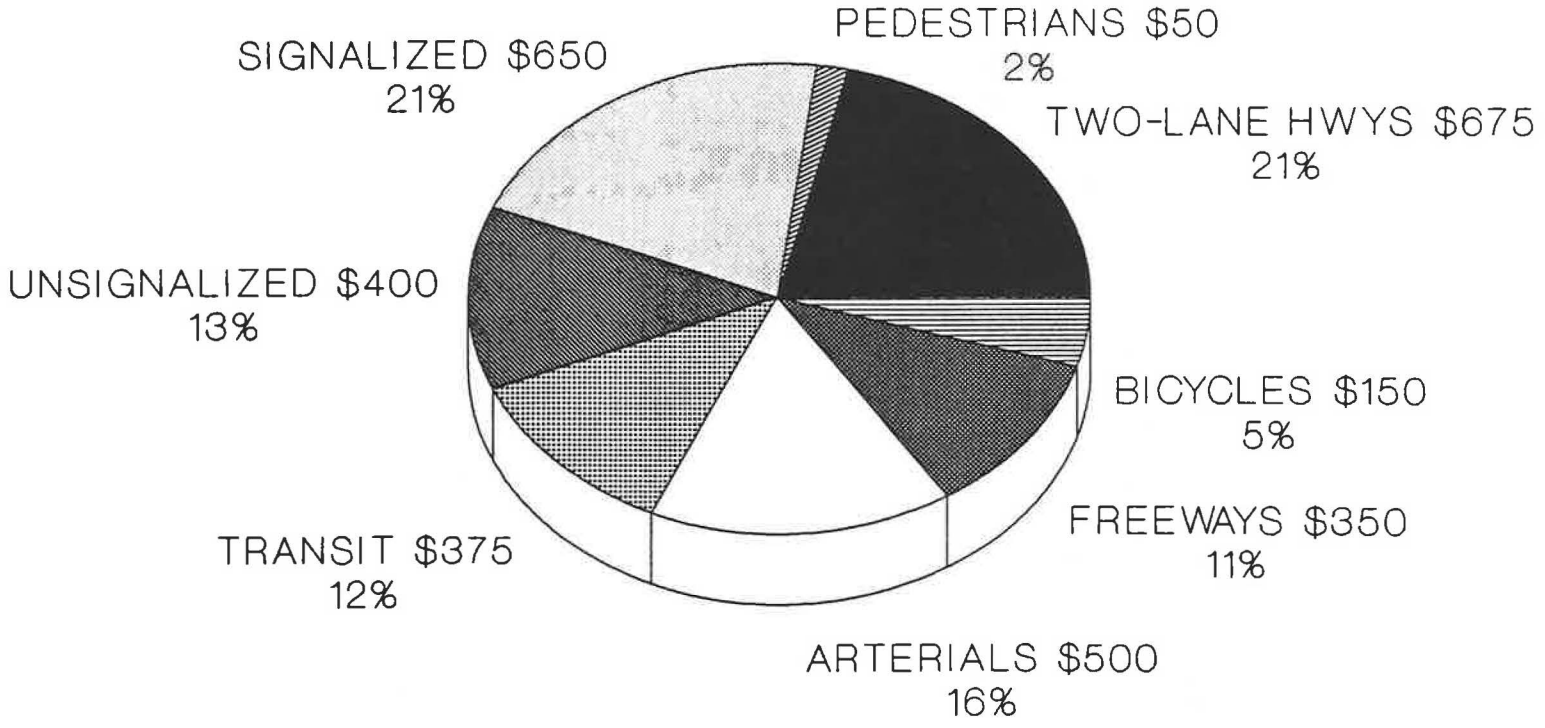
[1] Includes NCHRP 3-37, which is under contract for $400,000.
[2] Under Contract. NCHRP 3-37.

EXHIBIT I- PROJECT BREAKDOWN BY TOPIC IN 1985 HCM



TOTAL: 20 STUDIES

EXHIBIT II- NEW FUNDING BY TOPIC IN 1985 HCM (K$)



TOTAL:$ 3.15 Million

CHAPTER 3 IMPLEMENTATION PLAN

Establishment of Research Project Priorities

Establishing project priorities was carried out by means of a survey mailed out to all Committee and subcommittee members of the Highway Capacity and Quality of Service Committee.

In it, respondents were requested to rank the twenty research projects according to their perception of importance, urgency and the like. Subcommittee members were asked to vote only on projects submitted by other subcommittees to minimize bias. The response rate for the survey was 67% for committee members, 57.1% for subcommittee members and 61.1 % overall. The rankings were derived from 72 responses submitted to the Committee's Task Force on Research by November 23, 1990.

Exhibit III depicts the final rankings for the three subgroups, namely A3A10 committee members only, subcommittee members only and the combined membership. For each project, the weighted score was derived on the basis of the frequency of first place votes, second place votes, etc. received by individual projects.

There appears to be a good consensus on the top priority projects among all groups. Project 12, Arterial Traffic Operations was ranked first by all groups. Project 7, Development of a Planning Method for Signalized Intersections was ranked second by committee members, third by subcommittee members and second overall. In a similar manner, Project 11, Procedures for Capacity and LOS at Unsignalized Intersections, was ranked third by the committee members, second by subcommittee members and third overall. There were some minor discrepancies between rankings for other projects but it is interesting to note that of the top ten projects identified by the committee members, nine of these appeared on the top ten list of the subcommittee members and in a very similar order (a correlation coefficient of 0.80 was found between the responses of the two groups).

The top ten list included four projects on signalized intersections, three on arterials and one each on freeways, two lane highways and unsignalized intersections. Clearly, the thrust of the responses emphasizes the conduct of research in traffic signal capacity analysis at isolated intersections and arterials.

Finally, the following combined scores were computed for each subcommittee listed below in ascending order:

Subcommittee (# of Projects)	Weighted	Score-All Projects
Unsignalized Intersections	(1)	6.83
Signalized Intersections	(4)	7.91
Arterial Operations	(3)	8.25
Freeway Operations	(2)	9.09
Two-Lane Highways	(3)	10.06
Transit	(4)	13.89
Pedestrians/Bicycles	(3)	15.50

Project Scheduling and Financing

The proposed scheduling plan is depicted in Exhibit IV. A starting date of July 1st, 1991 is assumed for the program. Also depicted are the budgetary requirements for each project. Project priorities developed in the previous section are displayed in parentheses on the side of each bar. Exhibit V depicts the individual projects milestones, including dates for the interim and final reports and software development. It is shown that the entire research effort should be completed by 1997, leading the way for the revised Highway Capacity Manual chapters by the year 2000. In Exhibit VI, the distribution of annual budget is depicted, with a pronounced peaking in 1993. Finally, proposed sponsoring agencies for individual projects are listed in Exhibit VII.

Publication Plan

At this stage, there is no general consensus among the subcommittee chairmen on the best way to bring about a revised HCM upon completion of the proposed research program. This will be an important issue for deliberation by the entire membership meeting in January 1991 at TRB. There appears, however, to be some agreement on the following points:

1. Each research project (or combination of projects when applicable) should yield a revised draft of the pertinent chapter.
2. Individual subcommittees should be involved in project monitoring, and an "agreement in principle" of the proposed methodology must be given to the research contractor before developing the companion software.

EXHIBIT III - SUMMARY OF PROJECT RANKINGS BY A3A10 COMMITTEE AND SUBCOMMITTEE MEMBERS

Project Number	Project Title	Committee Members Only [20 of 30 responded] Rank	Weighted Score	Committee Members Excluded [24 of 42 responded] Rank	Weighted Score	Combined Membership [44 of 72 responded] Rank	Weighted Score
12	Arterial traffic operations	1	4.26	1	6.86	1	5.63
7	Development of planning method, signalized intx	2	4.36	5	8.56	2	6.72
11	Procedures for capacity and LOS, unsignal. intx	3	6.61	2	7.06	3	6.83
10	Capacity analysis with traffic-actuated control	6	6.87	4	7.56	4	7.24
2	Coordination of freeway research	4	6.65	7	9.05	5	7.95
8	Revision of operational method, signal. intx	5	6.86	6	8.83	6	7.97
6	Two-lane highways capacity and LOS procedures	9	9.00	3	7.29	7	8.17
13	Relating arterial time/space diagrams to LOS	7	8.21	8	10.10	8	9.20
9	Operational analysis of exclusive LT lanes	8	8.50	11	10.67	9	9.72
14	Arterial chapter coordination with other chapters	11	9.68	9	10.14	10	9.93
3	Survey of high volume locations	10	9.19	12	11.05	11	10.22
4	Survey of two-lane highways problems	14	11.33	10	10.35	12	10.86
5	Improved simulation of two-lane highways	12	10.67	13	11.71	13	11.17
15	Bus flows on multilane streets	13	11.21	15	12.74	14	12.05
16	Light Rail transit capacity on city streets	16	14.47	14	11.83	15	13.00
18	Revisions to HCM chapter 12: transit	15	13.84	16	13.96	16	13.91
19	Revisions to HCM chapter 13: pedestrians	17	15.11	17	14.35	17	14.69
21	Revisions to HCM chapter 14: bicycles	18	16.21	18	14.82	18	15.46
20	Uniterrupted bicycle flow characteristics	19	16.37	20	16.36	19	16.37
17	Effect of door width on transit service & capacity	20	16.95	19	16.33	20	16.60
		Mean:	10.32	Mean:	10.98	Mean:	10.68

Exhibit IV. Time and Budget Schedule - Proposed Research Program

Project Number	Project Title	YEAR 1991	1992	1993	1994	1995	1996	1997	Project Budget ($1,000)	Linked to No.
3	Survey of high volume locations	XXXXXX (11)							0	
1	Capacity of Ramp Freeway Junctions (NCHRP 3-37)	In progress	XXXXXX------							
7	Development of planning method, signalized intx	XXXXXX	XXXXXX (2)				(2)	XXXXXXXXXXX	100	8
4	Survey of two-lane highways problems	XXXXXX	XXXXXX (12)						75	
15	Bus flows on multilane streets	XXXXXX	XXXXXXXXXXX	XXXXXX (14)					150	
20	Uniterrupted bicycle flow characteristics	XXXXXX	XXXXXXXXXXX	XXXXXX (19)					100	
12	Arterial traffic operations	XXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXX (1)				250	15,16
11	Procedures for capacity and LOS, unsignal. intx	XXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXX (3)			400	
16	Light Rail transit capacity on city streets		XXXXXXXXXXX	XXXXXX (15)					100	
17	Effect of door width on transit serv. & capacity		XXXXXXXXXXX	XXXXXX (20)					75	
13	Relating arterial time/space diagrams to LOS		XXXXXX	XXXXXXXXXXX	XXXXXX (8)				250	
14	Arterial chapter coordination with other chapters		XXXXXX	XXXXXXXXXXX	XXXXXX (10)					
5	Improved simulation of two-lane highways		XXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	(13)			400	
2	Coordination of freeway research		XXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXX (5)			350	1
8	Revision of operational method, signal. intx		XXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXX (6)	400	
18	Revisions to HCM chapter 12: transit			XXXXXXXXXXX	(16)				50	15,16,17
9	Operational analysis of exclusive LT lanes			XXXXXX	XXXXXX (9)				50	8
21	Revisions to HCM chapter 14: bicycles			XXXXXX	XXXXXX (18)				50	
10	Capacity analysis with traffic-actuated control				XXXXXX	XXXXXX (4)			100	
19	Revisions to HCM chapter 13: pedestrians				XXXXXX	XXXXXX (17)			50	
6	Two-lane highways capacity and LOS procedures					XXXXXXXXXXX	XXXXXX (7)		200	
	Yearly Budget ($K)	230	707.5	962.5	685	355	145	65	3150	

* For additional details, review project statements

Note: Parentheses indicate project priority

Exhibit V. Milestones - Proposed Research Program

Project Number	Project Title	YEAR 1991	1992	1993	1994	1995	1996	1997	Project Budget ($1,000)	Linked to No.
3	Survey of high volume locations	----FL (11)							0	
1	Capacity of Ramp Freeway Junctions (NCHRP 3-37)	In progress	XXXXXX------							
7	Development of planning method, signalized intx	------	---CRC				(2)	---------CRC	100	8
4	Survey of two-lane highways problems	------	----FR (12)						75	
15	Bus flows on multilane streets	------	----------	------ (14)					150	
20	Uniterrupted bicycle flow characteristics	------	----IR------	----FR (19)					100	
12	Arterial traffic operations	------	----IR------	----IR----FR	SOF,CH (1)				250	15,16
11	Procedures for capacity and LOS, unsignal. intx	------	----IR------	----FR------	----CH------	---SOF (3)			400	
16	Light Rail transit capacity on city streets		----------	------ (15)					100	
17	Effect of door width on transit serv. & capacity		----------	------ (20)					75	
13	Relating arterial time/space diagrams to LOS		------	--IR,SOF--IR	SOF,FR (8)				250	
14	Arterial chapter coordination with other chapters		------	--IR,SOF--IR	SOF,FR (10)					
5	Improved simulation of two-lane highways		------	IR--------IR	------FR,SOF	(13)			400	
2	Coordination of freeway research		------	----IR------	----FR------	SOF,CH (5)			350	1
8	Revision of operational method, signal. intx		------	----FR------	----------	----SOF-----	----SOF-----	----TR (6)	400	
18	Revisions to HCM chapter 12: transit			----------CH	(16)				50	15,16,17
9	Operational analysis of exclusive LT lanes			------	----RR (9)				50	8
21	Revisions to HCM chapter 14: bicycles			----FR	SOF,CH (18)				50	
10	Capacity analysis with traffic-actuated control				------	----RR (4)			100	
19	Revisions to HCM chapter 13: pedestrians				----FR	SOF,CH (17)			50	
6	Two-lane highways capacity and LOS procedures					----IR----FR	CH,SOF (7)		200	

* For additional details, review project statements

Note: Parentheses indicate project priority

Definitions:

IR = Interim Report
FR = Final Report
SOF = Software
CH = Revised Chapter
O= Other

SF = Survey Form
DL = Draft List
FL = Final List
CRC = Circular
RR = Research Report
TR = Test Report

Exhibit VI– Proposed Annual Budget

For Research Program

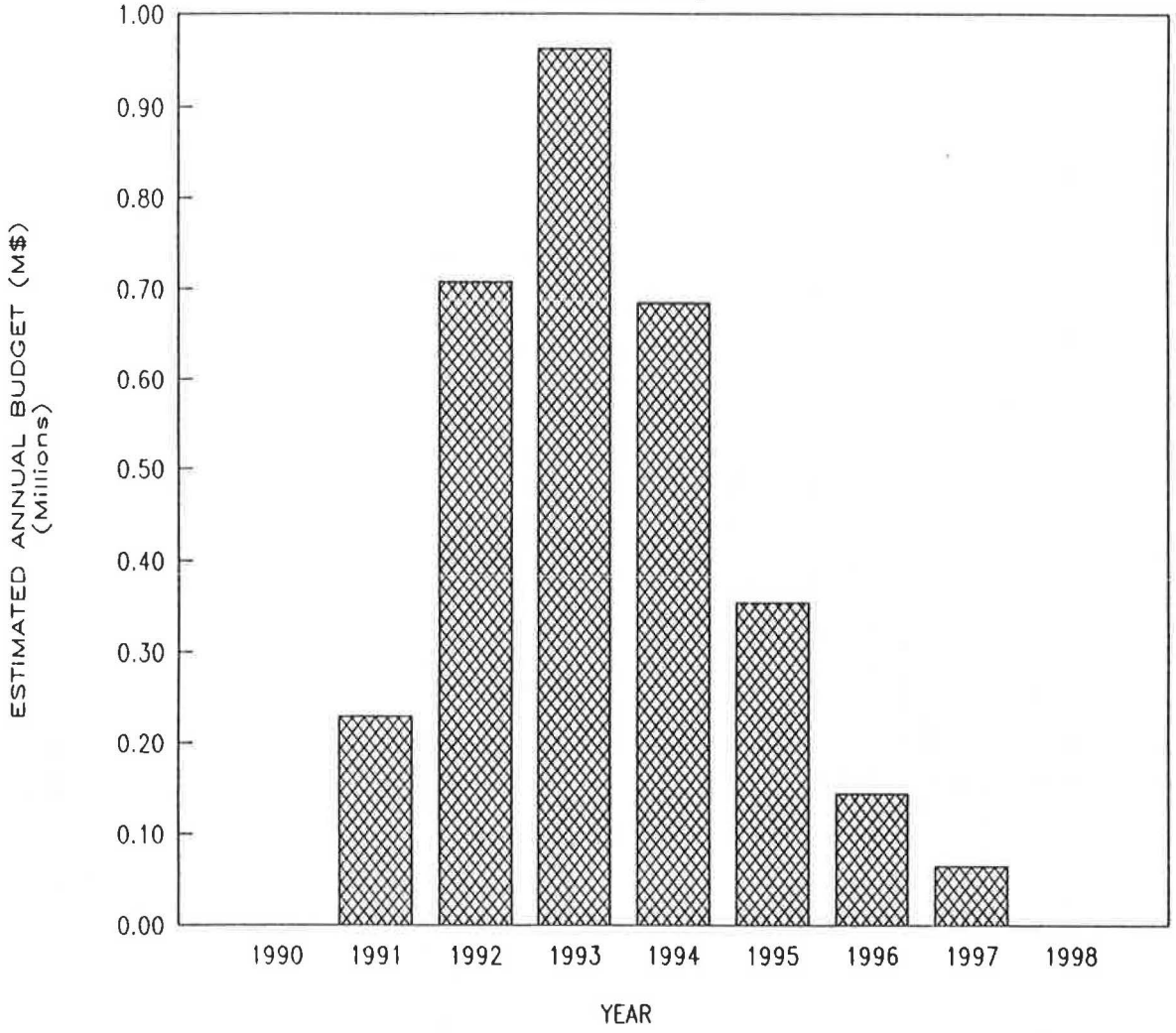


Exhibit VII - Proposed Sponsoring Agencies

Project Number	Project Title	Agency
1	Capacity of Ramp Freeway Junctions (NCHRP 3-37)	NCHRP 3-37
2	Coordination of freeway research	FHWA, NCHRP
3	Survey of high volume locations	Committee Activity
4	Survey of two-lane highways problems	FHWA, NCHRP
5	Improved simulation of two-lane highways	FHWA, NCHRP
6	Two-lane highways capacity and LOS procedures	FHWA, NCHRP
7	Development of planning method, signalized intx	FHWA, NCHRP
8	Revision of operational method, signal. intx	FHWA, NCHRP
9	Operational analysis of exclusive LT lanes	FHWA, NCHRP
10	Capacity analysis with traffic-actuated control	FHWA, NCHRP
11	Procedures for capacity and LOS, unsignal. intx	FHWA, NCHRP, RTC
12	Arterial traffic operations	FHWA
13	Relating arterial time/space diagrams to LOS	FHWA, NCHRP
14	Arterial chapter coordination with other chapters	NCHRP
15	Bus flows on multilane streets	UMTA, NCHRP
16	Light Rail transit capacity on city streets	UMTA, NCHRP
17	Effect of door width on transit serv. & capacity	UMTA, NCHRP
18	Revisions to HCM chapter 12: transit	UMTA, NCHRP
19	Revisions to HCM chapter 13: pedestrians	UMTA
20	Uniterrupted bicycle flow characteristics	FHWA, HP/R
21	Revisions to HCM chapter 14: bicycles	FHWA, HP/R

Definition:

FHWA = Federal Highway Administration
UMTA = Urban Mass Transportation Administration
NCHRP = National Cooperative Highway Research Program
RTC = Regional Transportation Center/ U.S. Dept. of Transportation
HP/R = State Dept. of Transportation Highway Program/Research funds

3. It is beneficial both to the Committee and to the user community to publish interim research results and methods (in TRB Circulars) as a means of gauging user understanding and assessment of the proposed methods.

4. Development of the final chapter drafts and coordination among chapters is best achieved through a separate contract with guidance from the Committee members. One suggestion was that two separate contracts be considered, one for Chapters 1-8 (Flow characteristics and uninterrupted flow facilities), and a second for the remaining chapters in the HCM. It must be noted that the cost for this contract is not considered in the proposed budget, and therefore needs to be added in the final plan (Estimates for this task range from $100K to $150K).

What remains unclear now is whether the HCQS Committee should pursue the publication of a brand new HCM in the year 2000, or simply replace/revise chapters in the present Manual as the need arises (based on research findings). As one subcommittee chairperson noted, the 1985 HCM was established as a loose-leaf document with the thought that individual chapters could be revised in an ongoing fashion. By asking the user community to wait until all research is completed, some material may indeed become obsolete by the time it actually put into use.

From the Task Force on Research viewpoint, this issue needs to be addressed by the entire committee. The ultimate goal, however, does not change. It is to produce the complete set of revised HCM chapters by the year 2000. Whether this is done on an incremental, chapter by chapter basis, or as an entirely new document does not affect the significance and urgency of carrying out the proposed program at the earliest possible date.

CHAPTER 4 PROGRAM SUMMARY FOR UNINTERRUPTED FLOW FACILITIES

Scope

This section covers Chapters 3 through 8 in the 1985 HCM, as well as the companion material in Chapters 1 and 2. Facilities include freeways components (basic, weaving and ramp-freeway segments), rural multilane highways and two-lane highways.

The major research problems identified in this program are ones which encompass definitions, parameter calibration with new data, completeness of existing procedures, and coordination among various chapters. Six research project statements (numbered 1 through 6) were developed to address these issues.

Research Issues

Freeways

Freeway operating characteristics are clearly changing. Empirical observations indicate that, in general, higher values of "reasonable expected capacities" are sustained on basic freeway sections than is presently stated in the Manual (2000 pcphpl). Indeed, a completed NCHRP study on multilane highways suggests a capacity of 2200 pcphpl for these facilities. This also suggests that the speed/flow relationship on freeways must be carefully reevaluated considering the new results. The HCQS Committee has been surveying state DOT's to obtain information on the maximum observed freeway flow rates (See project 3). There is a also a need for basic studies of the speed flow relationship considering new evidence suggesting different capacities at various free flow speeds.

Ramp junctions and weaving are another area of concern--primarily for Measures of Effectiveness (MOE) selection. In fact, freeway operational analysis would be improved by placing all freeway-related chapters on a more common LOS base. Ramp procedures have not been updated with a new data base since the 1965 HCM and performance characteristics are not even defined in the HCM. An NCHRP study of freeway/ramp junctions is now underway (see project 1) to evaluate and, if necessary, replace the HCM procedure in Chapter 5. There have been several weaving area studies since the publication of the 1985 HCM which need to be considered. Revisions to the weaving procedures should focus on evaluating these available alternate procedures, incorporate recent research results obtained in California and perhaps seek limited funding to expand the California effort to a nationwide sample. Chapter 6, Freeway Systems, being a derivative of Chapters 3-5 will be revised on the basis of the research results.

The design implications of the ongoing and proposed research are clear: if higher capacities than currently indicated in the HCM exist, then the potential savings due to greater efficiency in handling forecast volumes is great. If these increased capacities and efficiencies extend to ramp junctions and weaving areas, then interchange design can potentially be simplified and made less costly in many cases.

Finally, it is not anticipated that simulation models will be a major role in the freeway research component. Moreover, there is not a great deal of research on freeway operations outside the U.S. Some efforts are underway in Japan and Korea, but both are relying on the model structure of the HCM.

Multilane Highways

While no additional research is proposed for rural multi lane highways with the completion of the NCHRP study referred to earlier, coordination of its findings with other chapters (particularly freeways) is essential to avoid obvious conceptual pitfalls which would put into question the validity of the entire method. It goes without saying that the final draft and software arising from the research must be made consistent with other chapters.

Two-Lane Highways

Specific research issues were identified for two-lane highways, which will require a major revision in the existing procedures. Some of the weaknesses which currently exist in Chapter 8 of the HCM include poor agreement between the current procedures for general terrain segments and specific grades; lack of a method to evaluate the effect of operational improvements such as climbing lanes, passing lanes and turnouts, lack of a method to account for the effect of reduced design speeds on LOS; and overestimation of the effect of terrain on LOS. Failure to pursue the recommended research may result in highway agencies missing opportunities to use design and operational improvements because of the lack of a procedure to document their benefits. Project 4 is a preliminary effort intended to determine highway agencies needs for, and experience with, the existing Chapter 8 in the HCM and at establishing priorities for the remaining research.

Simulation models are viewed as essential tools for the development of a revised chapter. Chapter 8 was developed with TWOTAF (the predecessor to TWOPAS). Project 5 involves the development of improved simulation models for two-lane highways starting with two candidate models TWOPAS and TRARR (Australian model). The research will select the model that is in closest agreement with field data for North American cities and improve and calibrate that

model. Project 6 involves the use of the improved simulation model to develop a revised HCM Chapter. The simulation models would be also suitable for the evaluation of design decisions too complex for evaluation with an analytical procedure as an HCM chapter.

International cooperation is viewed primarily as a source of new ideas and concepts that can be incorporated in simulation and/or analytical modes. At its more recent meeting, the subcommittee reached a consensus that the HCM should provide a procedure calibrated to North American conditions. The subcommittee has members from Canada, Australia and a member who teaches in Columbia. Thus adequate international representation in key aspects of the proposed research is expected.

Research Problem Statements-
Uninterrupted Flow Facilities
1985 HCM Chapters 3,4,5,6,7 and 8

STUDY 1- FREEWAYS

Title: Capacity and Level of Service at Ramp-Freeway Junctions

NOTE: This study is scheduled to start in June 1990 as NCHRP Project 3-37.

Problem Statement

A more definitive understanding of capacity and level of service (LOS) at ramp-freeway junctions is needed to design new freeway interchanges and improve existing freeway interchanges.

Objectives

The objective of this research is to develop and validate an appropriate methodology for determining capacity and LOS at freeway-ramp junctions. This could take the form of modifications to the 1985 HCM methodology or an entirely new methodology. In either case, the product of this research shall be a consistent and comprehensive approach treating a wide range of ramp-freeway configurations and traffic conditions.

This research will: (1) evaluate the state of the art in operational analysis of ramp-freeway junctions, (2) develop and test a revised or new methodology for analyzing capacity and LOS at these junctions, and (3) verify the proposed method with an extensive field data collection effort.

Scope

To accomplish this objective, the project shall be performed in two phases:

Phase I

Task 1. Evaluate the adequacy of the procedures in Chapter 5 of the 1985 HCM. Survey users to determine their experience in applying the procedures to identify deficiencies and needed improvements. Evaluate new information and procedures that should be considered. Appraise the ability of current procedures to predict traffic flow phenomena and identify any deficiencies. This task will not require major field data collection.

Task 2. Propose an improved model or models where needed to overcome the deficiencies identified in task 1. The model(s) shall relate capacity and LOS to an appropriate set of site specific characteristics. The research shall consider the characteristics used in the current methodology and, as a minimum, consider the following additional characteristics: (a) angle of convergence/divergence; (b) length of acceleration/deceleration lane and recovery zone; (c) tapered vs. parallel design; (d) ramp roadway geometrics (including curvature, grades, sight distance, operating speed and width); (e) ramp vehicle arrival patterns specifically random arrivals, platoon arrivals, and ramp metered arrivals); (f) ratio of ramp to main line lane volumes; and (g) number of lanes and volume distribution on ramp and main line. In addition, other characteristics identified as having significant impact on capacity and LOS should be considered. The treatment of ramp configurations shown in figure 5-1 and table 5-2 of the HCM shall be extended to include those additional configurations identified in task 1. The recommended model(s) shall reflect changes in driver behavior and vehicle fleet and performance. Those characteristics and relationships that can be demonstrated to have no significant influence on capacity or level of service may be eliminated from future consideration. The proposed model(s) shall be based on a systematic approach which represents a rational and logical application of the principle of traffic flow. Modification or expansion of the LOS criteria may be considered, if warranted.

Task 3. Prepare a field data collection and analysis plan to quantify the traffic flow relationships among the parameter identified in task 2. The interval used for analysis shall not exceed 15 min. Investigate the existence of current usable field data before preparing the plan. Where possible, sites for data collection shall represent a variety of nationwide geographical locations, traffic demands, geometrics, and other key conditions. The plan shall identify the expected level of precision, sample size, specific costs, and priorities for each data collection category. A method for early identification of problems that may arise in the data collection and analysis shall also be included. The use of automated data collection techniques, such as video imaging, is allowed, but the development of such techniques is not an objective of this study.

An interim report shall be submitted for review by the NCHRP panel before proceeding with task 4. The interim report shall discuss the proposed model(s) and support any substantial changes from the existing methodology. It shall also describe the plan for data collection and analysis in detail.

Task 4. Select a minimum of five representative sites for a pilot study and implement the data collection and analysis procedures developed in task 3. Based on the data collected, evaluate the model(s) proposed in task 2.

Task 5. Prepare a Phase I report including (1) a preliminary evaluation of the proposed model(s), (2) the proposed data collection and analysis plan, and (3) a revised, detailed budget for Phase II. The data collection plan should include site selection for approximately 50 sites including those in the pilot study. The researchers shall meet with the NCHRP panel and appropriate members of TRB's Highway Capacity Committee for review and approval of the Phase I report before proceeding to Phase II. It is anticipated that a 60-day period will lapse between the submission and approval of the Phase I report.

Phase II

Task 6. Collect field data according to the approved plan. Data shall be collected under good weather conditions in daylight.

Task 7. Reduce and analyze the data collected under task 6 to calibrate the model(s). Select the appropriate model for inclusion in the final report.

Task 8. Prepare a final report describing the form and content of the capacity and level-of-service analysis procedures. This report shall include any procedural revisions necessitated by the data collection and analysis effort and the final values adopted for the relationships used in the analysis procedures. The level of precision and sensitivity of the procedures shall be estimated. This report will be subject to review and acceptance by the NCHRP panel and TRB's Highway Capacity Committee before starting tasks 9 and 10.

Task 9. Prepare a new version of HCM Chapter 5, "Ramps and Ramp Junctions" containing the new analysis procedures. This material shall follow the style of the 1985 HCM and shall be suitable for use without any changes, other than typesetting. Figures, tables, and photographs shall be in final camera ready form.

Task 10. Implement the procedures of this project in the HCS module for Ramp and Ramp Junctions which is currently distributed and maintained by the McTrans Center. This task will require modifying the existing module or preparing a new module. The modified or new model shall use the language, software standards, and "look and feel" of the HCS. Fully documented source code and modified user documentation shall be provided. The new version of the HCM Chapter 5 produced in task 9, and the new version of the HCS produced in task 10 will be reviewed and approved by the NCHRP project panel.

Cost: Phase I $100,000.
Phase II $300,000.

Duration: Phase I--12 months (including 2 months for review and revision of Phase I report and panel meeting) Phase II--24 months (including 3 months for review and revision of final deliverables).

STUDY 2-FREEWAYS

Title: Coordination of Freeway Research

Problem Statement

Speed-flow-density relationships and the effects of lane width and heavy vehicles are poorly understood for freeways. Separate, uncoordinated research is already being conducted in California (California study F87TO09: Procedures for Design of Weaving Areas Near One-Lane Ramps; F89TO25: Capacities of Urban Freeways; F88TO34: Development and Application of Procedures for the Design and Analysis of Freeway Weaving Sections; F89TO21: Further Development for Designing and Analyzing Freeway Weaving Sections; F88TO23: Freeway On-Ramp Design Standards) and Texas (Texas study 2-10-88-1196: Development of Planning and Capacity Values for Urban Freeways in Large Texas Cities). These studies attack isolated parts of the problem; they need to be coordinated and the gaps between them filled in. Also, there is a need to coordinate the research with findings from the multilane highways study just completed.

Objectives

Synthesize the results of ongoing or completed freeway research projects to gain a better understanding of freeway capacity concepts, of speed-flow relationships and for turbulence measures of various freeway components (basic segments, ramp junctions, weaving segments and freeway systems). Identify additional data needs to complement existing data base. Coordinate findings from multilane research.

Scope

Coordination of existing research, new data collection to reconcile differences and fill in "holes." Revision and possibly rewriting Chapters 3-6, coordination with Chapter 7 and development of companion software.

Data Requirements

20 sites x 2 days per site (estimated).

Cost

$350,000.

Duration

Three years.

STUDY 3- FREEWAYS

Title: Survey of High Volume Locations

Problem Statement

Much anecdotal evidence has accumulated about locations with traffic volumes greater than 2000 veh/lane-hr. The values cited in the *Highway Capacity Manual* are no longer credible. Recent findings on Multilane Highways capacities confirm this fact.

Objectives

Assemble a table of "record" volumes to replace Table 2-1 of the *Highway Capacity Manual*.

Scope

Nationwide mail survey.

Data Requirements

Mail survey to State DOTS, Urban Traffic Engineers Council, etc.

Cost

None. (To be conducted as an activity of the Freeway Subcommittee of the Transportation Research Board Committee on Highway Capacity and Levels of Service)

Duration

One year.

STUDY 4-TWO-LANE HIGHWAYS

Title: Survey of Two-Lane Highway Problems

Problem Statement

A better understanding is needed of user experience with Chapter 8 of the 1985 Highway Capacity Manual and of traffic operational problems on two-lane highways is needed. For example, it would be desirable to obtain more information from highway agencies about the need for climbing and passing lanes on two lane highways. There is no existing inventory of good high-volume data collection sites on two-lane roads.

Objectives

To determine the nature and extent of traffic operational problems on two-lane highways, the needs of HCM users and sources of existing data and unpublished information for consideration in subsequent research. This research should determine any weaknesses of the current HCM Chapter 8 as perceived by the users and should identify any significant operational problems on two-lane roads that are not addressed by the current Chapter. The lack of a method for evaluating the operational effectiveness of climbing and passing lanes is probably one of the more significant needs, but other needs such as including turnouts and shoulder usage and reconsideration of the basic measure of the quality of service (percent time delay) should be evaluated in the research. Potential data collection sites on high volume rural and suburban two lane roads throughout North America should also be identified.

Scope

Mail survey and follow-up interviews.

Data Requirements

Response from each State and Provincial highway agency. Consideration should be given to sending the survey to several respondents within each agency, including both headquarters and district office personnel.

Cost

$75,000

Duration

One year.

STUDY 5-TWO-LANE HIGHWAYS

Title: Improved Simulation of Two-Lane Highways

Problem Statement

Analysis of two-lane highway operations by simulation is much more advanced and reliable than analytical methods. However, there is a need to improve simulation capabilities both to include new features and to provide a basis for an improved capacity and level of service procedure. Simulation models could also be used to develop better analytical models of two-lane highway operations.

Objectives

Compare and evaluate existing two-lane highway simulation models and select the model that is in closest agreement with field data for North American conditions. Add new or upgraded capabilities such as graphical output. Calibrate the model with existing and new data on two-lane highway operations.

Scope

The project will include computer programming modification and verification against existing and new data. The two strongest candidates for selection as the simulation model of choice for two lane highways are the TWOPAS model (developed in research for FHWA) and the TRARR model (developed in Australia, but used by many researchers in the U.S. and Canada). Both models are microscopic simulations of two-lane highway operations and include the capability to simulate passing and climbing lanes. ROADSIM, an FHWA model based on earlier version of TWOPAS lacks this capability.

The project should include an extensive comparison of TWOPAS and TRARR against each other and field data. The decision concerning which model to select should be based on (1) agreement with field data, (2) range of available capabilities and (3) ease of updating and quality of available documentation. The selected model should be adjusted as necessary to improve its agreement with field data for North American conditions and updated to include desirable capabilities identified in Study 4.

Data Requirements

Calibration data may be available from current FHWA contract on Adjustment Factors for Lane-Width and Lateral Clearance. Additional data will be needed, for example, to calibrate and validate the passing and climbing lanes components of the revised model.

Cost

$400,000

Duration

30 months.

STUDY 6-TWO-LANE HIGHWAYS

Title: Two-Lane Highways Operational Analysis Procedure

Problem Statement

Although simulation methods may be more accurate, it is, nevertheless, necessary to have an analytical method to assess the capacity and level service of two lane highways. The method should be capable of paper and pencil or rapid computer solution. (All present capacity methods, including HCM Chapter 8 use this approach.)

Objectives

To develop an improved analytical procedure for capacity determination and level of service analysts. This procedure should be suitable for hand calculation but should give essentially the same results as the simulation program developed in Study 5.

Scope

Develop an analytical method for determining capacity and level of service for two-lane highways. Rewrite HCM chapter to incorporate new methodology and develop and test companion software.

Data Requirements

No field data should be needed. The analysis procedures will be based on results from the calibrated simulation model developed in Study 5.

Cost

$200,000.

Duration

18 months.

SUMMARY- PROJECT STATEMENTS CHAPTERS 3 THROUGH 8.

Study	Duration (yrs.)	Funding (K$)
1. Capacity and LOS at Ramp/Freeway Junctions.	3	400[a]
2. Coordination of Freeway Research.	3	350
3. Survey of High Volume Locations.	1	[b]
4. Survey of Two-Lane Highway Problems	1	75
5. Improved Simulation of Two Lane Highways	2.5	400
6. Two-Lane Highways Capacity Analysis Procedure	1.5	200
TOTAL		$1,425,000

[a] NCHRP 3-37, starting June 1990.
[b] Presently conducted as an activity of the Freeway Subcommittee.

CHAPTER 5 PROGRAM SUMMARY FOR INTERRUPTED FLOW FACILITIES

Scope

This section comprises Chapters 9 through 14 in the 1985 HCM, which cover capacity and LOS for signalized and unsignalized intersections, arterials, transit, pedestrian and bicycle facilities.

A key difference between research needs for interrupted vs uninterrupted flow facilities pertain to the implementation aspects and completeness of the 1985 HCM procedures. Throughout the open forums conducted by the HCQS committee and ITE, and continuing discussions at the HCQS 1989 midyear meeting, many practitioners questioned the ability of the present methods to adequately respond to the day-to-day needs of the traffic engineer and planner.

A total of fourteen project statements (numbered 7 through 21) covering the six chapters were developed to address the stated deficiencies as described below.

Research Issues

Signalized Intersections

The planning method of Chapter 9, signalized intersections, although ideally suited for application to projected designs (e.g., site impact analyses) has been severely criticized as being too gross even for planning purposes. The signalized intersection subcommittee is now in the process of developing a planning application of the operational analysis method using default parameters. Interim results are to be published in a Transportation Research Circular (See project 7, Phase 1). On the other hand, the operational analysis method, was criticized by some for its excessive detail, and by others for its lack of design capability (i.e., signal timing). Other issues concerning that chapter include the selection of LOS indicator (delay, v/c or some combination of both); the wisdom of constraining the computational methodology to what can be accomplished in a worksheet setting and the reconciliation of delays obtained from the HCM procedure with those derived from more sophisticated computer simulation/ optimization models (e.g PASSER and TRANSYT). It is also apparent that some improvements within the present methodologies are needed, particularly in the area of saturated flow rates calibration (a key ingredient in the design of signalized intersection approach geometrics), in modeling protected/permissive left turns and in defining and discriminating intersection performance on the basis of controller type (fixed time vs. actuated). Some of these problems can now be resolved with the completion of two recent studies dealing with progression effects on delays and operations of shared-permissive left turn lanes sponsored by NCHRP and FHWA.

The need for coordination between Chapters 9 and 11 (arterials) is evident, especially with regards to signal progression effects on arterials. The issue of "where" signal progression methods should reside in the Manual is an important one which must be resolved in future editions. As this chapter is by far the most heavily utilized by practitioners, it is imperative that adequate resources be made available to respond to the user community needs.

On the international scene, the signalized intersection subcommittee has added several eminent international scholars to its membership. In addition, a subcommittee member has been invited to conduct collaborative research on signalized intersections at the Australian Road Research Board in 1991.

Unsignalized Intersections

A major research funding thrust is needed in the area of unsignalized intersections. Not only is the part-way stop control (PWSC) procedure based on an obsolete 1972 West German method (with virtually no calibration data base in the U.S), but no procedure (design or operational analysis) presently exists in the U.S. for analyzing all-way stop controlled-intersections AWSC (1985 HCM data taken from a limited study in Evanston conducted in the early sixties). Furthermore, the concept of reserve capacity adopted in the PWSC method bears no resemblance to other chapters (especially Chapter 9), so that no one-to-one comparisons are possible between PSWC and signalized control. The University of Idaho has been a leader in PWSC and AWSC data collection, analysis and model development. It is however clear that a comprehensive data base needs to be compiled as a prerequisite to developing the revised methods. In the interim, the unsignalized intersection subcommittee is in the process of developing an interim method to be published in an upcoming transportation research circular, using the limited data base from Idaho.

Simulation models for TWSC conditions exist in West Germany and Britain. The utility of these models related to U.S. conditions should be determined in light of a data base describing U.S. driver characteristics. Gap acceptance parameters for U.S. conditions have been quantified as part of the calibration effort in NETSIM. The applicability of this data base to a revised TWSC method will be investigated where appropriate. Since simulation models were designed to overcome deficiencies found in traditional capacity analysis techniques, their role in the development of a revised HCM method is viewed as significant.

The Unsignalized Intersection Subcommittee is aggressively communicating and cooperating with the international research community in developing a revised concept for unsignalized intersection capacity analysis

through participation in international conferences (Bochum, W. Germany 1988 and 1991), appointment of international researchers to the subcommittee and organizing a conference session on that topic at TRB (January 1991).

Arterials

The current methodology for analysis of major arteries is largely an extension of the signalized intersection chapter. Although little user feedback is available about the extent to which this procedure is utilized, some of its limitations are evident. First, arterial LOS is predominantly governed by intersection delays, which in turn makes it difficult to produce reasonable LOS for short links. Furthermore, the method does not directly consider many midblock factors such as driveway density, parking, pedestrians, bus stops and blockages.

Finally, the phenomenon of arterial weaving is now being recognized as an important factor affecting arterial performance (New Jersey recently initiated a study on that problem).

Design has been very explicitly recognized as important in the existing Chapter 11 through using the arterial class as a basic input. The research proposed in Project 12 will further validate and modify this concept as necessary. Design of on-street parking and to some extent pedestrian facilities will be also considered.

Another important issue is how to relate arterial progression, typically expressed by the bandwidth concept to the progression concepts utilized in the Manual. While Project 13 is more likely to have an orientation to operations, a fundamental constraint in time space diagrams is the physical location of the signalized intersections.

There are strong ties between projects 15 and 16 (Transit) and the Arterials chapter. Bus and light rail operations are overwhelmingly occurring on arterial type streets. It is doubtful that bus and light rail operations were a major component of the FHWA sponsored arterial research. This program represents an excellent opportunity to link funding across chapters. The implementation plan provided for the arterial research seeks to stage the funding of projects 13 through 16 so that more detailed traffic operations and design research will be followed by transit related work (also with a very strong transit layout and street design component).

Simulation has a legitimate role in allowing us to model known phenomena and to extend empirical findings in ways that may otherwise be infeasible. Many of the research issues confronting the arterials subcommittee have not been explicitly included in FHWA simulation models development (e.g., midblock pedestrian interference, parking friction and arterial weaving). Research on a revised HCM can be used to expand, enhance and verify existing FHWA simulation activities.

International cooperation is not believed to be as critical to the Arterials chapter revisions as other chapters. More effort is needed however to coordinate with researchers in Australia and the U.K.

Transit

Transit, Pedestrians and Bicycle facilities have generally received less attention from the HCQS Committee and the user community. In addition to the strong interaction between transit projects 13 and 14 with the arterial work mentioned earlier, there is general agreement that the transit chapter should be simplified and updated and that additional research is needed to fill voids and validate assumptions. For example, material on bus PCE factors should be moved to the freeways, signalized intersection and arterial chapters where they are applied.

Research needs include the validation of PCE factors, bus operations on multilane streets, light rail operations on city streets and the relationship between passenger throughput and capacity utilization of transit vehicles. Thus, immediate funding by UMTA of the transit projects will undoubtedly generate results which can be used in other chapters of the revised Manual.

Pedestrian and Bicycles

The chapter on pedestrians will require some rewriting to incorporate findings of recent studies on crosswalk and corner analyses and some coordination with Chapter 9 regarding pedestrian effects on right turn movement saturation rates and lost times. A major limitation of the present chapter is that the present method is based overwhelmingly on New York City data. Project 19 is meant to address some of these deficiencies.

The principles of bicycle flow are not well known. Project 20 is meant to enhance the state of knowledge of the basic principles and relationships of uninterrupted flow facilities. As a result, the bicycle chapter will require some rewriting (project 21) and a small scale study of uninterrupted bicycle flow.

Research Problem Statements-
Interrupted Flow Facilities
1985 HCM Chapters 9,10,11,12,13 and 14

STUDY 7-SIGNALIZED INTERSECTIONS

Title: Revision of Planning Methodology for Signalized Intersections

Problem Statement

The planning method for signalized intersections is perceived by traffic practitioners as being too simplistic

for use in design and operational analysis applications; they also view the current operational analysis method as too cumbersome and data hungry. The planning method needs to be retooled to strengthen its analytical base and make it more amenable for use in site impact applications: the use of default adjustment factors for saturation flow rates in the operational method is another simplification issue. In essence, the planning method should be developed as an extension of and simplification to the more detailed operational analysis methodology.

Objectives

To revise the planning methodology for signalized intersections to maximize its acceptability and use by traffic personnel and coordinate its methodology with the operational analysis procedure.

The signalized intersections subcommittee has made substantial progress on the development of a substitute for the current planning method. Instead of parallel method, we propose to create a planning application for the operational analysis method. It is possible to apply default or synthesized values for all of the operational input data except for traffic volumes, number of lanes, parking status and left turn protection on each approach. With site-specific values for these four items, a worksheet has been developed which will produce appropriate choices for the rest of the data items.

Scope

It is proposed that this project be broken into two phases, each of which will require 12 months to complete. Phase 1, which is given top priority, will involve the development of a TRB Circular which will contain the new planning application, plus three other revisions which are now under consideration.

1. Revised progression delay model (NCHRP 3-28C).
2. Revised shared permitted left turn lane model (FHWA).
3. Improved protected+permitted left turn lane model, with a concept similar to the model used in SIDRA, PASSER II, TRANSYT or other traffic signal analysis programs.

Phase 2 should be carried out after projects 8, 9, and 10. It will provide for the adaptation of the planning application to the improved operational method which will be produced by those projects.

Data Requirements

No field data collection is required. The technique requires extensive testing using existing data.

Cost

Phase 1: $60,000
Phase 2: $40,000

Duration

One year for each phase.

STUDY 8-SIGNALIZED INTERSECTIONS

Title: Revision of Operational Analysis Method for Signalized Intersections

Problem Statement

The 1985 HCM operational analysis procedure is by far the most utilized and criticized portion of the Manual. There is a need to reconsider both the empirical basis and computational methodology of the procedure. This project is predicated on a decision by the HCQS Committee to drop the requirements for a manual worksheet to implement Chapter 9 methodology. Empirical relationships obtained in the field could be used to a large extent toward the development of a time-based deterministic accumulation/discharge model to estimate the operating parameters required for the computations of delays and LOS. The procedure could be simplified accordingly to form the basis of the planning methodology.

Objective

To validate and/or revise existing methodology by replacing aggregate cycle-based relationships to instantaneous simple relationships among variables. The relationships will be founded upon strong empirical evidence gathered through extensive field studies.

Scope

It is proposed to carry out the study in four phases:

Phase 1, Assessment: A detailed analysis of the shortcomings and potential remedies will be required prior to actual model development. It is anticipated that the basis of implementation of the new technique will advance beyond the worksheets concept. Several alternatives will be investigated including worksheets, spreadsheets, computer algorithms, simulation models and expert systems. The output of this phase will be the framework of the model to be developed.

The limitations of scope, range and accuracy must be identified at this stage. The need for coordination with

other HCM chapters and other traffic control system analysis methods must also be identified.

Phase 2, Model Development: The model itself must be developed and calibrated using an appropriate combination of theoretical and empirical modelling. The efforts on this phase should provide answers to all of the questions identified in phase 1. Coordination with the development of related models for other HCM chapters should be maintained.

Phase 3, Model Implementation: The model or models must be incorporated into a user-oriented product. The nature of the product will depend on the outcomes of Phases 1 and 2.

Phase 4, Model Testing: The product of Phase 3 must be thoroughly tested before it is released for general use. The test efforts should be independent of the developer.

Data Requirements

Extensive. Saturation flow rate models must be calibrated and collected in a way that is consistent with the revised methodology. Additionally, validation data to confirm the relationship between instantaneous variables is needed (e.g., left turn saturation flow vs opposing flow). A comprehensive data base of nationwide scope will be involved.

Costs

$400,000

Duration

5 years from the beginning of the assessment phase to the end of the testing phase.

STUDY 9-SIGNALIZED INTERSECTIONS

Title: Operational Analysis of Exclusive Left Turn Lanes

Problem Statement

One of the apparent weaknesses in Chapter 9 is the lack of an adequate methodology for analyzing left turns from exclusive lanes. Issues to be addressed are saturation flow adjustment factors for protected, permissive, protected/permissive and permissive/ protected phasing; relationship between phase sequence and adjustment for progression; splitting of demand among protected and permitted portions; saturation flow rates to be used in the delay equations; validation of FHWA study results from shared lanes (methods results should converge when a shared lane operates as exclusive lane); validation of dual left turn lanes factors; effect of turn bay length on capacity utilization.

Objective

To complete revisions on left turn factors (in conjunction with FHWA study and international work, e.g., Akcelik) and address an area of criticism in Chapter 9.

Scope

Assemble, review and interpret existing research effort to produce revised methodology. Coordinate work with Study 8.

Data Requirements

None. Analytical models by Allsop, Bonneson and Mc. Coy, and Akcelik could be tested. Local data in Arizona (1986-1988), Illinois (1989- 1991) should be sufficient to validate or modify existing methodologies.

Cost

$50,000 to synthesize and produce final methodology.

Duration: One year.

STUDY 10-SIGNALIZED INTERSECTIONS

Title: Capacity Analysis for Intersections with Traffic Actuated Controllers

Problem Statement

Chapter 9 procedures were calibrated primarily from fixed-time controlled intersections. As most recent signal installations are of the actuated type (fully/semi/volume-density), there is a need to validate the existing methodology with actuated controllers. Issues such as signal parameters (e.g., average cycle, average greens, etc.) delay models and progression effects need be addressed for those controllers.

Objective

To validate or refine current Chapter 9 methodology to better represent actuated control operations.

Scope

Coordination of existing research (Jovanis work in Illinois, NCHRP 3-28C, FHWA contract DTFH61-87-C-00012,etc.) to sort out actuated control data. Possibly new, but limited, data collection. Coordinate with Studies 8 and 9.

Data Requirements

Limited measurements of delays and saturation flow rates to fill in gaps in existing data base for ALL types of actuated controllers.

Cost

$100,000

Duration

Two years.

STUDY 11-UNSIGNALIZED INTERSECTIONS

Title: New Procedures for Capacity and Level of Service Analysis at Unsignalized Intersections

Problem Statement

The following major deficiencies exist in Chapter 10 of the Highway Capacity Manual dealing with the operational analysis of unsignalized intersections.

1. The Two-Way-Stop-Control (TWSC) Method is based on the 1972 West German method that is no longer being used. Furthermore, the calibration data base for the method is very limited in the U.S.
2. No formal procedures exist for the analysis of All-Way-Stop-Control (AWSC) and roundabouts (quite popular in Europe and Australia).
3. The reserve capacity measure of level of service used in this Chapter is not consistent with the delay measure used for signalized intersections, so that comparative evaluation of the signalized and unsignalized control at an intersection is not possible.
4. The operation of unsignalized intersection within coordinated signal systems is not adequately represented.
5. The method is not applicable for planning purposes and does not relate to the warrants for installing signals in the MUTCD.

Objective

The research would examine analysis methods, conduct validation studies, recommend revised computational methodologies and calibrate the recommended procedures that are needed to replace the outdated procedures in Chapter 10. A secondary objective is to relate the analysis procedure to the warrants for installation of signals in the MUTCD so that consistent mitigation measures can be proposed.

Scope

Field calibration and validation of proposed models to complement local data collection and analysis efforts in the Northwest. Review new procedures developed in Germany (Brilon) and Great Britain (Seamens). Ascertain the utility of traffic simulation models (Tracz) in filling holes where empirical data lacks. Rewrite chapter and companion software.

Data Requirements

Subcommittee on Unsignalized Intersections is developing a uniform data collection Manual. Data will be the focus of short term work toward the development of an interim procedure (Study 5).

Effectiveness

The resolution of these problems through the proposed research is a critical link in providing the traffic engineering community with a valid procedure to analyze the large number of unsignalized intersections that are planned or already exist.

Cost

$400,000

Duration

4 years.

STUDY 12-ARTERIALS

Title: Arterial Traffic Operations

Problem Statement

The present arterial methodology in Chapter 11 is predominantly governed by intersection delays. Midblock factors such as intersection spacing, driveway density, parking, median access design, bus stops and pedestrians are not explicitly accounted for in LOS evaluation beyond the "arterial class" designation. Moreover, the impact of arterial weaving is all but ignored. Weaving tends to reduce overall travel speed (as in freeways) as well as platoon coherence. It may well be that some of the given geometric and traffic variables will ultimately negate the beneficial impacts of progression, particularly in dense urban settings.

Objective

To quantify by means of analytical models and empirical observations the effect of geometric and traffic variables (primarily midblock) on arterial operation.

Scope

Field observations of different arterial configurations. Analytical model calibration and validation.

Data Requirements

Some data is already available from the TTI progression study and an ongoing weaving study in New Jersey. Supplemental data for midblock factors need to be collected at approximately 30 sites nationwide.

Cost

$250,000

Duration

Three years.

STUDY 13-ARTERIALS

Title: Relating Arterial Time/Space Diagrams and LOS

Problem Statement

For design purposes, a time/space diagram is sometimes the only item of information available regarding the operation of a projected arterial system. The diagram is drawn manually or may be generated in TRANSYT, MAXBAND, or PASSER II. How can these designs be related to a projected arterial LOS, especially if no detailed intersection analysis has been performed (e.g., to calculate delays and progression adjustment factors). This is an important issue that addresses the credibility and potential usability of the method in Chapter 11. It may be that we need to consider the sole use of signal systems models in lieu of the arterial chapter, supplemented with empirical models of geometric factors not presently incorporated in such models.

Objective

To develop methods for relating time/space diagram concepts to arterial LOS (e.g., bandwidth efficiency/attainability, etc.). Apply method for projected conditions, where data is insufficient for detailed intersection/arterial analysis.

Scope

Collect existing information from current research (NCHRP 328C, Courage, Rouphail, Olsewzsli, and Bonneson) to revise and supplement Chapter 11. Perform simulation analyses to reconcile differences between HCM and simulation models MOE's. Possibly upgrade the simulation models to incorporate more geometric and traffic factors.

Data Requirements

None. Use existing data (particularly from Study 12) and methods to synthesize findings.

Cost

$150,000.

Duration

Two years.

STUDY 14-ARTERIALS

Title: Arterial Chapter Coordination with Other Chapters

Problem Statement

There is a need to coordinate arterial LOS methodology with other chapters in the Manual. For instance, should progression effects be computed at the intersection or arterial level? (Chapters 11 & 9). How do platoons affect gap availability and subsequently operations at unsignalized intersections in the system (Chapter 11 & 10)? How does arterial bus and light rail operation effects lane use and signal progression (Chapter 11 & 12).

Objective

To address coordination issues for an arterial system and its components. Develop material that specifically addresses this issue to be located at the end of each chapter. Alternatively, rewrite Chapters 9 through 12 under "Urban/ Suburban Street System" umbrella.

Scope

Gathering, analyzing and synthesizing existing information in subject chapters and from current research. Based on the findings of Studies 11, 12 and 13 rewrite chapter and update software.

Data Requirements

None.

Cost

$100,000 if a major rewrite of an urban street package is contemplated, $50,000 otherwise.

Duration

One to two years depending on alternative.

STUDY 15-TRANSIT

Title: Bus Flows on Multilane Streets

Problem Statement

The capacity of a bus lane, where buses must follow each other is well established. However, there is relatively little information on how bus capacity is increased as buses have full or partial use of the adjacent lane (i.e. dual bus lanes). In some cases, it is possible for buses to effectively pass each other, with the ease of such movements depending upon the traffic flows in the adjacent lanes.

Objective

To collect data on bus use of adjacent lanes, as a function of the adjacent lane traffic flow; also to investigate the actual operation of dual bus lanes.

Scope

Collect, calibrate and validate relationships between bus flows in curb and adjacent lanes with car flows in the adjacent lanes. Assess dwell times, and use, of stops as well.

Data Requirements

Needs are three to four sites in each of three to four large metropolitan areas.

Cost

$150,000

Duration

Two years.

STUDY 16-TRANSIT

Title: Light Rail Transit Capacity on City Streets

Problem Statement

The capacity of Light Rail Vehicles (LRV's) where they run on private right-of-way and/or on fully grade-separated right-of-way can be computed in a similar fashion to Rapid Transit. On city streets, however, with short block spacings and frequent signals, there is no viable model of the factors that influence LRV capacity and its effects on other traffic.

Objective

To identify the effects of train length, dwell times, block spacing and signal cycle length on the number of trains and cars per hour that can be accommodated with minimum spillback onto adjacent blocks. Also verify the cumulative effects on the capacity of other traffic modes.

Scope

Data collection to empirically observe the interaction among variables of interest. Analytical model development.

Data Requirements

Needs are three to four sites at three or four major metropolitan areas in the U.S. and Canada.

Cost

$100,000

Duration

Eighteen months.

STUDY 17-TRANSIT

Title: Effect of Door Width on Passenger Service Times, Dwell Times and Capacity

Problem Statement

Most passenger service times have been derived from surveys of passengers boarding and alighting through single channel doors. Data in the 1985 HCM for multiple channel doors were derived in various research studies. There is a need to validate these data, based upon various mixes of entering and exiting passengers.

Objective

Obtain new parameters for passenger service times (and dwell times) for passengers boarding and alighting buses and LRV's (Study 15) through multiple channel doors. Incorporate results into an updated chapter.

Scope

Collect data from few U.S. and Canadian bus systems (LRV data could be collected as part of Study 15) that use multiple channel doors.

Data Requirements

Needs are five to six sites in each of three to four cities in North America.

Cost

$75,000

Duration

Eighteen Months.

STUDY 18-TRANSIT

Title: Revision of the Highway Capacity Manual Chapter 12: Transit

Problem Statement

The current capacity material on transit is not presented in a manner consistent with the rest of the Highway Capacity Manual. There is a need to edit, simplify and update the material in this Chapter.

Objectives

To rewrite an abbreviated HCM chapter on transit by removing some material to other chapters (ex: PCE factors should be moved to freeway and signals chapters), and relegating formulae and calculations to an Appendix. Also incorporate updated findings of studies 14-16 into the revised draft.

Scope

Rewrite, edit and update existing material and update software accordingly.

Data Requirements

No new data required. The arterial and transit studies in this program will provide some data on bus and LRV operations, capacity and flow characteristics.

Cost

$50,000

Duration

One year.

STUDY 19-PEDESTRIANS

Title: Revisions in the Highway Capacity Manual Chapter 13

Problem Statement

There is a need to revise some of the methods in Chapter 13 to incorporate new research findings in the areas of crosswalk and corner analyses. In addition, the topic of bicycle/pedestrian interface in recreational areas and campus environment has not received much attention.

Objective

Incorporate new research findings into a revised draft. Review international efforts in this domain (e.g., the Netherlands) and produce updated Chapter and software.

Scope

Incorporate completed and ongoing research results in the U.S. and elsewhere into Chapter 13.

Data Requirements

Minimal. Existing data in the literature could be used as the primary source.

Cost

$50,000

Duration

One year.

STUDY 20-BICYCLES

Title: Uninterrupted Bicycle Flow

Problem Statement

In certain areas bicycles are becoming a significant means of transportation. Rules for determining the capacity and level of service of uninterrupted bicycle facilities are needed.

Objectives

To establish the principles of bicycle flow on a basis similar to that for highway traffic so that bicycle capacity can be estimated and facilities designed to provide specified levels of service.

Scope

Existing literature and expert opinion. Limited data collection.

Data Requirements

Limited to site conditions not available in the literature (e.g., high density bicycle flow corridors).

Cost

$100,000.

Duration

Two years.

STUDY 21-BICYCLES

Title: Revision of Highway Capacity Manual Chapter 14: Bicycles

Problem Statement

Recent research has increased our knowledge of bicycle operations. This material could be used to improve upon the existing Bicycle Chapter of the 1985 HCM.

Objective

Revise and expand on existing material in the HCM. Incorporate recent research on uninterrupted bicycle flow. Update and revise material on bicycle effects at signalized intersections. Expand material to include operational characteristics in recreational areas. Develop companion software for inclusion into HCS.

Scope

Limited to existing research results and data.

Data Requirements

None.

Cost

$75,000

Duration

1 year.

SUMMARY-PROJECT STATEMENTS CHAPTERS 9 THROUGH 14

Study	Duration (yrs)	Funding (K$)
7. Revision of Planning Method for Signalized Intersections.	2	100
8. Revision of Operational Method for Signalized Intersections.	5	400
9. Operational Analysis of Exclusive LT lanes.	1	50
10. Capacity Analysis of Traffic Actuated Controllers.	2	100
11. New Procedures for Capacity and LOS at Unsignalized Inters.	4	400
12. Arterial Traffic Operations.	3	250
13. Relating arterial BW Design to LOS.	2	150
14. Arterial Chapter Coord. with other Chapters.	2	100
15. Bus Flows on Multilane Streets.	2	150
16. Light Rail Transit Capacity on City Streets.	1.5	100
17. Effect of Door Width on ... Transit Capacity.	1.5	75
18. Revision of Chapter 12, Transit.	1	50
19. Revision of Chapter 13, Pedestrians.	1	50
20. Uninterrupted Bicycle Flow Characteristics.	2	100
21. Revision of Chapter 14, Bicycles.	1	50
TOTAL		$2,125,000