



TRANSIT COOPERATIVE RESEARCH PROGRAM
Sponsored by the Federal Transit Administration

TCRP

REPORT 100

2nd Edition

Transit Capacity and Quality of Service

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AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, The National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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NOTICE

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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The Transportation Research Board of The National Academies, the National Research Council, the Transit Development Corporation, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

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FOREWORD TO THE SECOND EDITION

The *Transit Capacity and Quality of Service Manual* (TCQSM) is intended to be a fundamental reference document for public transit practitioners and policy makers. The manual contains background, statistics, and graphics on the various types of public transportation, and it provides a framework for measuring transit availability and quality of service from the passenger point of view. The manual contains quantitative techniques for calculating the capacity of bus, rail, and ferry transit services, and transit stops, stations, and terminals. Example problems are included.

Material from this document that is relevant to traffic engineering is also included in Chapters 14, “Transit Concepts,” and Chapter 27, “Transit,” of the *Highway Capacity Manual 2000*, which is available from TRB in printed and CD-ROM versions.

Until the publication of *TCRP Web Document 6: Transit Capacity and Quality of Service Manual*, First Edition, the transportation profession lacked a consolidated set of transit capacity and quality of service definitions, principles, practices, and procedures for planning, designing, and operating vehicles and facilities. This is in contrast to the highway mode, where the *Highway Capacity Manual* (HCM) defines quality of service and presents fundamental information and computational techniques related to quality of service and capacity of highway facilities. The HCM also provides a focal point and structure for advancing the state of knowledge. It is anticipated that the TCQSM will provide similar benefits.

“Transit capacity” is a multifaceted concept that deals with the movement of people and vehicles; depends on the size of the transit vehicles and how often they operate; and reflects the interaction between passenger traffic and vehicle flow. “Quality of service” is an even more complex concept that must reflect a transit user’s perspective and must measure how a transit route, service, facility, or system is operating under various demand, supply, and control conditions.

The First Edition of the TCQSM was developed under TCRP Project A-15, conducted by a team led by Kittelson & Associates, Inc. This project (a) included market research on what potential users would like to see in a TCQSM, (b) assembled and edited existing information on transit capacity, and (c) provided results of original research on measuring transit quality of service. The First Edition, released in 1999, introduced an “A” to “F” classification framework for measuring transit availability and comfort/convenience at transit stops, along transit routes, and for transit systems as a whole.

A team led by Kittelson & Associates, Inc. addressed gaps in the First Edition by executing the following tasks:

- Arranging for transit agencies, metropolitan planning organizations, and others to apply and evaluate, in their own environments, the quality of service concepts and thresholds. In addition, comments from others who independently applied the quality of service framework were solicited and reviewed.
- Soliciting and analyzing comments on the First Edition, through an Internet site and other forums, and coordinating with the TRB Task Force on Transit Capacity and Quality of Service (A1E53).
- Supplementing the material in the First Edition to more thoroughly address quality of service and capacity implications of service for persons with disabilities.

- Identifying updated passenger service time information available from the literature and from industry sources.
- Reviewing the weaknesses of the “transit-supportive-area-served” measure of service coverage, and suggesting improvements to the measure.
- Creating an alphabetized index of the First Edition.

Based on the results of these tasks, a plan was developed for additional research needed to address identified gaps and to produce this Second Edition. This plan included the following tasks:

- Identifying the effects of transit preferential treatments on bus operations.
- Developing a pedestrian accessibility factor to be incorporated into the service-coverage measure.
- Developing passenger service times for low-floor light-rail vehicles and buses accepting multiple fare media.
- Performing an assessment of the standards by which on-time performance achievements are measured by transit agencies.
- Quantifying the contribution of park-and-ride lots to transit access.

Several significant structural changes have been made to the TCQSM between the First and Second Editions. Most notably, the part on quality of service has been moved in front of the capacity parts to reflect user interest in this section and the importance of quality of service to successful transit services. Demand-responsive transit quality of service has been given a chapter of its own, with measures entirely separate from fixed-route transit.

“Planning Applications” chapters have been added to the bus- and rail-transit capacity chapters, and an entirely new part on ferry capacity has been added.

Other major changes include expanded sections on transit-priority treatments, bus rapid transit, and commuter-rail capacity; and a new section on ropeway (e.g., aerial tramway, funicular, and cable-hauled people-mover) capacity. Also, the stop, station, and terminal capacity part has been expanded to address system interactions of different station elements and the sizing of station facilities to accommodate certain “event” conditions.

TRB has established a Committee on Transit Capacity and Quality of Service that will be responsible for guiding the long-term development and evolution of this manual.

AUTHOR ACKNOWLEDGMENTS

The Second Edition of the TCQSM was developed under TCRP Project A-15A. The TCRP Project A-15A team consisted of Kittelson & Associates, Inc. (prime contractor), assisted by KFH Group, Inc., Parsons Brinckerhoff Quade & Douglas, Inc., and Dr. Katherine Hunter-Zaworski.

Alan Danaher, P.E., PTOE, AICP, Senior Principal, Kittelson & Associates, Inc., was the principal investigator. Co-investigators were Paul Ryus, P.E., Associate Engineer, Kittelson & Associates, Inc.; Elizabeth (Buffy) Ellis, AICP, Senior Transportation Planner, KFH Group, Inc.; Mark C. Walker, Senior Planner, Parsons Brinckerhoff Quade & Douglas, Inc.; and Dr. Katherine Hunter-Zaworski, Assistant Professor, Oregon State University.

Part 1, Introduction and Concepts, was developed for the Second Edition by Alan Danaher.

Part 2, Transit in North America, was originally written for the First Edition by Tom Parkinson, P. Eng., President, Transport Consulting Limited, and was edited and expanded for the Second Edition by Paul Ryus. Updated transit statistics were compiled by Helen Donoway, Jessica Wineberg, and Kelly Blume of Kittelson & Associates, Inc.

Part 3, Quality of Service, was originally written for the First Edition by Paul Ryus, with contributions from Tom Parkinson, and was updated by Paul Ryus for the Second Edition. Buffy Ellis led the development of Chapter 4 on demand-responsive transit quality of service. Peter Haliburton, Pr. Eng. of Kittelson & Associates, Inc., led the development of the detailed service coverage factors, and Miranda Blogg, Ph.D., of Kittelson & Associates, Inc., led the development of the park-and-ride service coverage material.

Part 4, Bus Transit Capacity, was originally written for the First Edition by Paul Ryus and updated by him for the Second Edition. The material in the First Edition was developed from a number of sources, particularly Chapter 12 (Transit) of the 1985, 1994, and 1997 editions of the *Highway Capacity Manual*, authored by Herbert S. Levinson. Timothy Lomax and Bill Eisele of the Texas Transportation Institute contributed to Chapter 4 (Busways and Freeway HOV Lanes). Chapter 5 (Arterial Street Bus Lanes) is a condensed version of research developed by Kevin St. Jacques of Wilbur Smith Associates, Inc., and Herbert S. Levinson that is presented in TCRP Report 26 and TCRP Research Results Digest 38. Appendix B (Dwell Time Data Collection Procedure) was authored by Lewis Nowlin, Assistant Research Scientist, Texas Transportation Institute. Peter Haliburton also contributed material to the First Edition. Peter Koonce, P.E., Kittelson & Associates, Inc., added material on transit preferential treatments for the Second Edition, and Judith Gray and Kelly Blume, Kittelson & Associates, Inc., updated passenger service time information.

Part 5, Rail Transit Capacity, was originally written for the First Edition by Tom Parkinson, with the assistance of Ian Fisher, based on their prior work presented in TCRP Report 13. Paul Ryus edited the material for the Second Edition, expanded the Commuter Rail Capacity chapter, and added the Ropeway Capacity chapter.

Part 6, Ferry Capacity, was developed for the Second Edition by Miranda Blogg.

Part 7, Stop, Station, and Terminal Capacity, was originally written for the First Edition by Alan Danaher and updated by Mark C. Walker for the Second Edition. A major source for Part 7 was *Pedestrian Planning and Design*, by John Fruin. Lewis Nowlin and Daniel Fambro of Texas A&M University also contributed to this part in the First Edition.

Part 8, Glossary, was compiled from a number of sources for the First Edition by Tom Parkinson. Definitions have been obtained from numerous sources with acknowledgment and thanks to the many individuals and committees involved—in particular, Benita H. Gray, editor of the 1989 TRB Urban Public Transportation Glossary, from which almost one-half of the entries originated. The TRB glossary is out of print. Other major sources are APTA web site glossary (April 1998); National Transportation Statistics Glossary; Washington State DOT Glossary; TCRP A-8 Rail Transit Capacity Glossary; APTA Glossary of Reliability, Availability, and Maintainability Technology for Rail Rapid Transit 1993; draft NCHRP 8-35 ITS Glossary (including material developed by the FHWA, FTA, and U.S. DOT Joint Program Office); ANSI B77.1 aerial ropeway definitions; and a 1985 U.S. Forest Service glossary on aerial tramways, ski lifts, and tows. The contributions of Ian Fisher in compiling and cross-referencing the glossary are acknowledged. Kelly Blume updated the glossary for the Second Edition.

Part 9, Index, was developed for the Second Edition by Kelly Blume.

Katherine Hunter-Zaworski provided input throughout the TCQSM on addressing capacity and quality of service issues for persons with disabilities and on Americans with Disabilities Act (ADA) regulations.

Wayne Kittelson, P.E., Senior Principal, Kittelson & Associates, Inc., reviewed the First and Second Editions; John Zegeer, P.E., Principal, Kittelson & Associates, Inc., also reviewed the First Edition.

The project team would particularly like to thank the agencies and staff who volunteered to apply and comment on the First Edition's quality of service framework. Their assistance and input was invaluable in helping to shape the version of the framework appearing in the Second Edition. Participants included

- *Chicago*: Regional Transportation Authority—Mary Lupa; Chicago Transit Authority—Kenneth E. Dallmeyer and Catherine V. Quinn; Metra—Dana Long, A. Christopher Wilson, and Gary Foyle; PACE—Brad Thompson and Dick Brazda; and Chicago Area Transportation Study—Mark Thomas.
- *Albuquerque*: SunTran—Bill Slauson.
- *Gainesville, Florida*: City of Gainesville—Linda Dixon; Regional Transit System—Jesus Gomez and Maria Savoia; North Central Florida Regional Planning Council—Marlie Sanderson, Gerry Dedenbach, and Lynn Franson-Godfrey; and University of Florida—Linda Crider.
- *Northwest Missouri*: OATS—Mike Landy and Linda Yaeger.

In addition, several organizations independently applied the quality of service framework and provided feedback to the project team. These included Tara Barteo and Ike Ubaka of the Florida Department of Transportation Public Transit Office, who sponsored statewide evaluations; Victoria Perk of the Center for Urban Transportation Research, who conducted follow-up analyses and interviews associated with the Florida statewide evaluation; Lucie Ayer, AICP and Beth Malaby, AICP of the Hillsborough County Metropolitan Planning Organization and Diana Carsey of Hartline, who applied the framework in Tampa; and Brett Wallace, Wilbur Smith Associates, Inc., who applied the framework in Birmingham, Alabama.

Thomas W. Kowalski, President/CEO of Urban Transportation Associates, Inc., and Steve Callas of TriMet provided automatic vehicle location data used to test the reliability service measures.

The New York MTA Office of the Inspector General provided suggestions incorporated into the Second Edition: Iris Berman provided input used to update the passenger loading service measure and Gary Henderson provided input on the effects of bus bunching on capacity. Lawrence F. Hughes, AICP, of Varsity Transit,

provided feedback used to update the passenger loading and headway adherence service measures.

The Institute of Transportation Engineers student chapters at Morgan State University, the University of South Florida, and the University of Maryland collected data in Baltimore, Tampa, and Washington, D.C., respectively, to update bus fare collection service times. Fare collection service time data were collected in Portland, Oregon, by Dave Vest, Erin Ray, Elisa Leverton, Mollie Uselman, and Monica Leal. The American Society of Civil Engineers student chapter at the University of Portland collected data to update low-floor light-rail boarding and alighting times.

Ralph Bentley of Kittelson & Associates, Inc., developed much of the graphic art used in the TCQSM and Ben Worsley developed the CD-ROM's introductory page.

Finally, the project team would like to express its appreciation for the dedicated work of the TCRP Project A-15/A-15A panel. The majority of the panel members, who are listed elsewhere in this front section, have been involved with the development and oversight of both editions of the TCQSM throughout a 6-year period. The panel provided many thoughtful comments that have helped shape the current form of the manual. The guidance provided by the TCRP Program Officers for the First and Second Editions, Stephen J. Andrie and S.A. Parker, respectively, is also greatly appreciated.

All web addresses provided in the TCQSM were current at the time this report was produced, but are subject to change.

Internet addresses are subject to change.

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