NCHRP
SYNTHESIS 378

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

State Highway Cost Allocation Studies

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH BOARD 2008 EXECUTIVE COMMITTEE*

OFFICERS

Chair: *Debra L. Miller, Secretary, Kansas DOT, Topeka*
Vice Chair: *Adib K. Kanafani, Cahill Professor of Civil Engineering, University of California, Berkeley*
Executive Director: *Robert E. Skinner, Jr., Transportation Research Board*

MEMBERS

J. BARRY BARKER, *Executive Director, Transit Authority of River City, Louisville, KY*
ALLEN D. BIEHLER, *Secretary, Pennsylvania DOT, Harrisburg*
JOHN D. BOWE, *President, Americas Region, APL Limited, Oakland, CA*
LARRY L. BROWN, SR., *Executive Director, Mississippi DOT, Jackson*
DEBORAH H. BUTLER, *Executive Vice President, Planning, and CIO, Norfolk Southern Corporation, Norfolk, VA*
WILLIAM A.V. CLARK, *Professor, Department of Geography, University of California, Los Angeles*
DAVID S. EKERN, *Commissioner, Virginia DOT, Richmond*
NICHOLAS J. GARBER, *Henry L. Kinnier Professor, Department of Civil Engineering, University of Virginia, Charlottesville*
JEFFREY W. HAMIEL, *Executive Director, Metropolitan Airports Commission, Minneapolis, MN*
EDWARD A. (NED) HELME, *President, Center for Clean Air Policy, Washington, DC*
WILL KEMPTON, *Director, California DOT, Sacramento*
SUSAN MARTINOVICH, *Director, Nevada DOT, Carson City*
MICHAEL D. MEYER, *Professor, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta*
MICHAEL R. MORRIS, *Director of Transportation, North Central Texas Council of Governments, Arlington*
NEIL J. PEDERSEN, *Administrator, Maryland State Highway Administration, Baltimore*
PETE K. RAHN, *Director, Missouri DOT, Jefferson City*
SANDRA ROSENBLOOM, *Professor of Planning, University of Arizona, Tucson*
TRACY L. ROSSER, *Vice President, Corporate Traffic, Wal-Mart Stores, Inc., Bentonville, AR*
ROSA CLAUSELL ROUNTREE, *Executive Director, Georgia State Road and Tollway Authority, Atlanta*
HENRY G. (GERRY) SCHWARTZ, JR., *Chairman (retired), Jacobs/Sverdrup Civil, Inc., St. Louis, MO*
C. MICHAEL WALTON, *Ernest H. Cockrell Centennial Chair in Engineering, University of Texas, Austin*
LINDA S. WATSON, *CEO, LYNX–Central Florida Regional Transportation Authority, Orlando*
STEVE WILLIAMS, *Chairman and CEO, Maverick Transportation, Inc., Little Rock, AR*

EX OFFICIO MEMBERS

THAD ALLEN (Adm., U.S. Coast Guard), *Commandant, U.S. Coast Guard, Washington, DC*
JOSEPH H. BOARDMAN, *Federal Railroad Administrator, U.S.DOT*
REBECCA M. BREWSTER, *President and COO, American Transportation Research Institute, Smyrna, GA*
PAUL R. BRUBAKER, *Research and Innovative Technology Administrator, U.S.DOT*
GEORGE BUGLIARELLO, *Chancellor, Polytechnic University of New York, Brooklyn, and Foreign Secretary, National Academy of Engineering, Washington, DC*
SEAN T. CONNAUGHTON, *Maritime Administrator, U.S.DOT*
LEROY GISHI, *Chief, Division of Transportation, Bureau of Indian Affairs, U.S. Department of the Interior, Washington, DC*
EDWARD R. HAMBERGER, *President and CEO, Association of American Railroads, Washington, DC*
JOHN H. HILL, *Federal Motor Carrier Safety Administrator, U.S.DOT*
JOHN C. HORSLEY, *Executive Director, American Association of State Highway and Transportation Officials, Washington, DC*
CARL T. JOHNSON, *Pipeline and Hazardous Materials Safety Administrator, U.S.DOT*
J. EDWARD JOHNSON, *Director, Applied Science Directorate, National Aeronautics and Space Administration, John C. Stennis Space Center, MS*
WILLIAM W. MILLAR, *President, American Public Transportation Association, Washington, DC*
NICOLE R. NASON, *National Highway Traffic Safety Administrator, U.S.DOT*
JAMES RAY, *Acting Administrator, Federal Highway Administration, U.S.DOT*
JAMES S. SIMPSON, *Federal Transit Administrator, U.S.DOT*
ROBERT A. STURGELL, *Acting Administrator, Federal Aviation Administration, U.S.DOT*
ROBERT L. VAN ANTWERP (Lt. Gen., U.S. Army), *Chief of Engineers and Commanding General, U.S. Army Corps of Engineers, Washington, DC*

*Membership as of May 2008.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 378

State Highway Cost Allocation Studies

A Synthesis of Highway Practice

CONSULTANTS
PATRICK BALDUCCI
Battelle Memorial Institute
Portland, Oregon
and
JOSEPH STOWERS
Sydec, Inc.
Reston, Virginia

SUBJECT AREA
Planning and Administration

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2008
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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

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

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

NOTE: The Transportation Research Board of the National Academies, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

NCHRP SYNTHESIS 378

Project 20-5 (Topic 38-04)
ISSN 0547-5570
ISBN 978-0-309-09801-4
Library of Congress Control No. 2007910445

COPYRIGHT PERMISSION

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee 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 committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

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

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

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

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academys p urposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

FOREWORD

By Staff
Transportation
Research Board

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail Staba
Senior Program Officer
Transportation
Research Board

This synthesis examines the history and evolution of Highway Cost Allocation Study (HCAS) practice, and reports on the current state of the practice. This report is designed to aid states by laying the foundation required to build on current thought and improve current HCAS methods. This report addresses numerous issues, including what states have completed cost allocation studies, the conceptual basis of HCAS methods, methods used to allocate the costs associated with many highway program elements, methods for revenue attribution, and emerging HCAS issues.

Information for the study was obtained through review of literature and a survey of state transportation agencies that have performed HCASs. Eleven key states are highlighted: Arizona, California, Idaho, Indiana, Kentucky, Maine, Minnesota, Nevada, Oregon, Texas, and Vermont. The study also reports on survey responses on procedures for completing both traditional HCASs and for conducting HCAS analysis in new and emerging areas.

Patrick Balducci, Battelle, Portland, Oregon, and Joseph Stowers, Sydec, Inc., Reston, Virginia, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

STATE HIGHWAY COST ALLOCATION STUDIES

SUMMARY

In 1937, Oregon conducted the nation's first highway cost allocation study (HCAS), a study designed to determine the fair share that each class of road user should pay for the construction, maintenance, operation, improvement, and related costs of state highways, roads, and streets. Since that first HCAS, at least 84 studies have been performed in 30 states. The Oregon "cost-occasioned" approach—based on the principle that costs are occasioned by highway-user classes and can be attributed to each class based on measures of relative travel, space requirements, and loadings—has served as the foundation of nearly every state HCAS. Some of the most significant advancements, however, have occurred as the result of three federal HCASs completed in 1965, 1982, and 1997.

In recent years, states have adapted a wide variety of techniques to allocate the costs associated with highway use and to attribute revenue to highway-user classes. Further, new transportation technologies and revenue initiatives have added opportunities and uncertainty regarding highway-user tax structures. Thus, the topic of this synthesis report is both timely and important. This report is designed to aid states by laying the foundation required to build on current thought and improve current HCAS methods. This report addresses numerous issues, including which states have completed cost allocation studies, the conceptual basis of HCAS methods, methods used to allocate the costs associated with many highway program elements, methods for revenue attribution, and emerging HCAS issues.

To address these issues, the research team conducted an extensive literature review and implemented a survey, which was distributed to all 50 state departments of transportation. A good representation of state experience was reported, with 33 of the 50 states responding. Nearly all states that are known to have completed an HCAS since the 1982 Federal HCAS responded to the survey. The 33 reporting states also include a good representation of states that have not completed HCASs since 1982.

The results of the literature search and survey indicate:

- The motivation behind the HCAS is the achievement of equity. Historically, equity has been one of the most important principles driving tax policy, and has been considered when raising revenues and allocating funds for maintenance, capital improvements, operating programs, and services to the public. HCASs can aid in achieving equity-related objectives.
- State HCASs aid states in many ways. They can be used to develop recommendations for changes to the highway tax structure or changes in rates in existing tax and fee schedules. They can be helpful in informing legislative proposals that may impact the equity of the tax structure; equity among vehicle classes; equity for users of different parts of the highway system; or equity among users at different times of the day, days of the week, or for different periods of time over a forecast time period.
- Any state that does not perform HCASs is subjecting highway users to possible changes in the direction of less equitable tax structures without having credible information to aid decision makers in avoiding such decisions.

- HCASs, by the very nature of the detailed analyses required, can provide highway planners, programmers, policy analysts, financial officers, and top-level decision makers with critically important information to assist in ways to improve their programs.
- HCASs can aid states in planning more feasible steps in the direction of improved equity when giant steps toward an ideal tax structure are not feasible for either political or other important policy reasons.
- From 1982 to 2007, 25 states are known to have conducted HCASs. In 19 of the 22 studies referenced within this report, estimated payments were less than the cost allocated to heavy-truck classes.
- Over the last decade since the 1997 Federal HCAS was completed, no major changes in HCAS practice have occurred. The most significant recent activities in HCAS research have included
  - Completion of the FHWA's work on development and refinement of the National Pavement Cost Model (NAPCOM);
  - FHWA's development of NAPCOM into a model that can be relatively easily applied in state HCASs;
  - FHWA's development of generalized state HCAS software building on the results of the 1997 Federal HCAS and 1999 Oregon HCAS;
  - As part of the FHWA software development effort, the development of documentation for analyses needed for inputs to the software for state HCASs;
  - Vermont's successful use of the FHWA State HCAS Model and documentation with minimal outside consultant effort;
  - Oregon's continued evaluation of numerous HCAS issues in the issue papers supporting its HCAS and its continued exploration of performing a full cost-based allocation study where instead of allocating expenditures, the costs that are imposed on the system are directly allocated to highway user classes; and
  - FHWA's continuing refinement of data collection programs by the states as a cooperative effort, resulting in better comparability of data among the states.
- Historically, there has been a surge in the number of HCASs conducted at the state level immediately following the completion of federal HCASs. Ten HCASs have been performed since 2000 and two states (Arizona and Oregon) have conducted more than one study during this time. There were a number of reasons cited in the survey for the decline in the number of HCASs being conducted, including an increased emphasis on revenue generation in states facing constrained budgets, an inability on the part of most state tax structures to fully implement HCAS findings, a lack of leadership in addressing the equity issue in the transportation tax structure, and constrained research budgets that are used on other higher priority research.

This synthesis examines the history and evolution of HCAS practice, and assesses the current state of HCAS practice. It highlights HCAS work that has been performed in 11 key states: Arizona, California, Idaho, Indiana, Kentucky, Maine, Minnesota, Nevada, Oregon, Texas, and Vermont. It also provides a detailed and extensive set of procedures for completing both traditional HCASs and for conducting HCAS analysis in new and emerging areas. Finally, it presents general conclusions and suggestions for further research.

CHAPTER ONE

INTRODUCTION

In 1937, Oregon conducted the nation's first highway cost allocation study (HCAS). Since that first HCAS, at least 84 studies have been performed in 30 states. An HCAS is a study that is designed to determine the fair share that each class of road user should pay for the construction, maintenance, operation, improvement, and related costs of state highways, roads, and streets. Through a comparison of user fees paid and cost responsibilities estimated within the HCAS, these studies assess equity, usually for a projected period, and may provide recommended adjustments to existing user fees and tax rates to bring about a closer match between payments and cost responsibilities for each vehicle class.

Ultimately, an HCAS is an analysis of the equity of highway-user tax systems. Thus, it seeks to answer such questions as:

- Do highway users as a whole pay the full cost of highways or are they subsidized by non-users? Do they subsidize non-users and, if so, how much subsidy occurs?
- How do broad classes of highway users compare with each other in terms of paying their estimated shares of highway costs? Are some classes of users overpaying or underpaying and, if so, by how much?
- Are there specific changes in the tax structure or tax rates that will improve equity among highway users?

In addition to assessing equity in the current tax structure, HCASs can be useful in addressing a number of other tax issues. For example, HCASs can be used to develop special permit fee schedules for overweight vehicles or implement marginal cost pricing through toll- or mileage-based fee schedules for specific vehicle classes, differentiated by weight and configuration.

Ideally, HCASs are conducted within the framework of specific policies and procedures that are agreed on by both the legislative and executive branches of government. Broad-based agreement on the principles underlying the HCAS is important because the results of the study are intended to lead to the modification of tax and fee schedules in a manner that most effectively achieves equity and/or efficiency in the tax structure. Only rarely, however, have states achieved this ideal framework. Movement toward this goal has been achieved in some states through legislation authorizing an HCAS or a statement of intent to reach this ideal framework.

HCASs are often conducted: (1) because of the necessity to routinely (e.g., every 2 to 5 years) monitor the need for adjustments in tax rates, (2) because of the perceived need for changes in tax and fee schedules, (3) because of perceived problems in the inequity of the current tax structure, or (4) because of basic changes in the highway program that raise questions about who should be paying for the program.

Historically, HCASs have generally been conducted on an infrequent basis without any clearly defined prior commitment to follow up with legislative or executive action. Legislative recommendations often follow the completion of an HCAS, with mixed results, ranging from adoption of study recommendations to ignoring or openly rejecting them. With that noted, HCAS results generally influence policy makers as they consider making changes to existing transportation tax structures, although in many cases actions are taken after some period of debate and deferral. Further, HCASs are also valuable because they can be used to inform responses to legislative bodies regarding a wide variety of tax-related issues.

PROJECT GOALS AND SCOPE

The overall goal of this project is to assist states in performing comprehensive HCASs. At least 30 state governments have at some time conducted these studies to evaluate their systems of state road user charges, fees, and taxes. Studies vary in depth and scope. To date, results have been mixed. This synthesis compares and contrasts what has been completed by various states and seeks to provide guidance for future studies based on this experience.

To assist states in performing comprehensive HCASs, this project provides practitioners with information to improve their process of evaluating cost responsibilities, attributing revenue, and implementing study results. Both federal and state highway agencies utilize HCASs to evaluate their revenue systems and to maintain a cost-based user system.

States have adapted a wide variety of techniques and conventions to estimate highway use and the payment of user fees by vehicle classes. This study examines the HCAS state of the practice by addressing numerous questions and issues, including:

- States that have completed cost allocation studies;
- Software used in the cost allocation study;
- Vehicle classes and how they are differentiated;
- Functional class of the road systems considered in HCASs;
- Conceptual basis of HCAS methods;
- Methods used (e.g., cost-occasioned, marginal costing, and benefits analysis);
- Selecting appropriate cost allocators;
- Methodologies for revenue allocation [e.g., vehicle miles of travel (VMT), number of vehicles, roads used, and over-the-road weights];
- Treatment of diversions of highway-user revenues to other uses (e.g., law enforcement and education);
- Implementing cost responsibility in the presence of tolling and other facility-specific fees;
- Relationships between vehicle characteristics and roadway usage and capacity demands;
- Relationships between vehicle characteristics and pavement damage;
- Methodologies for allocation of load- and non-load-related pavement and bridge costs; and
- Emerging issues (e.g., allocating costs associated with congestion, air pollution, noise, human health, and property damage).

STUDY APPROACH

To address the issues listed previously in this section, the research team conducted an extensive literature review and implemented a survey that was distributed to all 50 state departments of transportation (DOTs). The research team used available in-house resources and facilities to identify relevant literature. The research team reviewed a broad spectrum of technical material, ranging from industry trade journals to university databases. The following sources of information and literature were reviewed:

- Proceedings of TRB annual meetings;
- *Transportation Research Records*;
- Transportation Research Information Services (TRIS) bibliographic database;
- National Transportation Library;
- U.S.DOT, FHWA;
- State DOTs;
- Web of Science and National Technical Information Service (NTIS) website;
- Industry representatives.

A highway cost allocation study bibliography is presented at the conclusion of this report.

The research team, working with TRB staff, also conducted a survey of all 50 state DOTs. The survey questionnaire is presented in Appendix A. Before sending the questionnaire to state DOTs, a test survey was completed by representatives of the Arizona DOT and Vermont Agency of Transportation (VTrans). Based on comments received from these reviews, a revised questionnaire was sent to all members of the AASHTO Standing Committee on Highways, which is comprised primarily of directors of highway agencies. Copies were also sent to all of the other members of the Standing Committee on Highways, and all members of AASHTO's Committee of Planning Directors for their information and advance notice that the state HCAS questionnaire might be forwarded to them by their state DOT or highway director.

Appendix B contains a detailed report on the results of the survey. A good representation of state experience has been reported, with 33 of the 50 states responding. States that responded included nearly all that are known to have completed HCASs since 1982, the year of the federal study that made the most ambitious improvements in research and study methodology. The 33 reporting states also include a good representation of states that have not completed HCASs since 1982, thus providing a good indication of why many states do not perform these studies.

This report is comprised of six chapters, including this introduction. Chapter two documents the history and evolution of state HCASs in the United States from 1982 to the present. In chapter three, there is an examination of the state of the practice regarding numerous key methodological issues dealt with in state HCASs. Why state HCASs are performed and what impact they have is discussed in chapter four. Chapter five includes an extensive set of guidelines for analyzing state data in a comprehensive HCAS and for responding to a wide variety of other opportunities and challenges relating to the equity of tax structures, emerging issues, problems in implementing HCAS findings, dealing with the roles of different levels of government, and others. In chapter six, there are study conclusions and recommendations including an evaluation of options to improve the prospects for the future of state HCASs in response to recent challenges.

The report also includes references, an HCAS bibliography, a list of acronyms, and a glossary. In addition, the report contains three appendices. Appendix A is the state HCAS survey questionnaire that was distributed to state DOTs. Appendix B summarizes the results of the survey. Appendix C contains a letter from the Vermont Agency of Transportation detailing problems with the FHWA State HCAS Model.

CHAPTER TWO

HISTORY AND EVOLUTION OF HIGHWAY COST ALLOCATION STUDIES

In 1937, Oregon conducted the nation's first HCAS. Oregon, more than any other state, was an early pioneer in terms of both the development and implementation of state HCASs, conducting five studies before the groundbreaking Federal HCAS completed in 1982 and implementing a three-tier system of highway taxation (registration fees, fuel taxes, and weight-mile taxes on heavy trucks) with the flexibility to fully implement the findings of the HCAS. Ten other states performed HCASs before the 1982 federal study—Arkansas, Colorado, Florida, Georgia, Kansas, Maine, Mississippi, New Mexico, Washington, and Wyoming. Federal HCASs were conducted in 1965, 1982, and 1997.

HIGHWAY COST ALLOCATION STUDY METHODS

Before the 1982 Federal HCAS, the methodology used in most state HCASs was some form of what is called the "Incremental Method," which was the set of methods developed in Oregon and refined in the major benchmark Federal HCAS conducted between 1957 and 1965 and published in 1965. The Incremental Method assigns responsibility for highway costs by first determining the costs of constructing and maintaining facilities for the lightest vehicle class and then building the facility up to account for the costs attributed to each increment of larger and heavier vehicles. All vehicles are allocated the costs of the base highway system in proportion to their usage of the highway system, as if they all had the same size and weight. The additional costs of accommodating heavier and larger vehicles are defined as their occasioned incremental costs, which could be avoided if those additional classes were excluded from the highway system.

Following the 1982 Federal HCAS, states across the nation adopted the "Federal Method." The Federal Recommended Method, or simply the Federal Method, was developed during the 1979 to 1982 Federal HCAS by adapting the older Incremental Method procedures for some expenditure elements and by developing new procedures for other elements. The Federal Method is a mixed approach. It applies a consumption approach to pavement rehabilitation and some related work, while applying the traditional Incremental Approach or other methods for expenditure elements that could not be viewed as consumed by highway use.

One reason for the shift from the Incremental to the Federal Method was that the former approach gave larger and heavier vehicles the undeserved benefit of economies of scale inherent in the provision of pavement strength. That is, each additional inch of pavement depth up to a certain point can support an increasing number of equivalent single-axle loads (ESALs) during the design life of the pavement. What made the shift possible was the revolution in computer technology combined with major achievements in relevant highway research.

The Federal Method, or variations on the Federal Method, gradually became accepted practice during the 1980s. The 1996 to 1997 Federal HCAS used this basic approach with several important refinements, the most significant of which was the development and application of the National Pavement Cost Model or NAPCOM. The FHWA continued to develop and refine NAPCOM over a 10-year period during the 1990s. Refinements made as part of the 1997 Federal HCAS made the model practical for use by states.

NAPCOM applies a set of pavement deterioration analyses to a large sample of pavement sections to determine what types of deterioration will occur and which vehicles are responsible for each type of deterioration. Heavy axles cause more damage per passage than light axles. For some types of pavement deterioration, doubling the axle load causes 15 to 20 times as much damage; for other types of deterioration, doubling the load only doubles the damage. NAPCOM was developed because traditional approaches using simplistic ESALs did not mesh well with empirical data on pavement wear (*Federal Highway Cost Allocation Study Final Report* 1997). The 1999 Oregon HCAS was the first state study to use NAPCOM to allocate pavement costs (Stowers et al. 1999).

Several state HCASs developed and applied both the Incremental Method and the Federal Method, including the first California study (1985 to 1987), the 1989 to 1990 Vermont study, and the 1989 to 1991 Minnesota study. These have been the two most commonly used methods in the United States. Almost all of the more recent state HCASs have used the Federal Method and variations or refinements of that approach [Arizona (1991 to 1995), Nevada (1992), California (1995 to 1997), Idaho (1994 and 2000), and several others].

Oregon has explored performing a full cost-based allocation study that moves away from allocation of highway

expenditures and includes external or social costs. The most recent Oregon HCAS presented two examples to illustrate the difference between cost- and expenditure-based approaches. When considering studded tire damage, the costs far exceed the expenditures, as evidenced by the extensive presence of rutted roads in that state. To the extent that road expenditures fall short of what is required to fix the problem, the full costs are not allocated to the highway users. Also, Oregon has embarked on a major bridge rehabilitation program with related expenditures having a significant effect on the results of the HCAS. The expenditures associated with this major restoration effort will bear little resemblance to the costs imposed on the system during the period when the reconstruction is occurring. Thus, nearly all HCASs do not allocate full costs; rather, they allocate responsibility for the expenditures tied to the highway program.

States have also considered applying the benefits-based approach. In this approach, the benefits tied to the use of roadway systems would be measured and allocated to highway users. This method results in an extension of HCASs to non-users. Extending the study to non-users is theoretically valid to the extent that non-users, or society, benefit directly from the roadway network; however, this approach is complicated because the great bulk of non-user benefits are actually second- or third-round benefits passed on through benefits to highway users. It is very difficult to distinguish such pass-through non-user benefits from other non-user benefits. Basing the HCAS on benefits received would enhance efficiency, as those who benefit from the road system would be required to pay in proportion to the benefits received. This approach, however, has not been used at the state level for a number of reasons. First, the benefits cannot be measured directly. Second, the data required to understand the full benefits of the system and allocate those costs between competing interests would be much larger than current HCAS data requirements. Third, benefits accrue to individuals as both a user and a non-user of a system. Further, some benefits are already allocated in the marketplace. For example, the benefits tied to the transport of goods by heavy trucks are recovered through shipping costs, which are paid by the ultimate consumers of products. Thus, it would be difficult to accurately capture the full range of benefits that need to be considered in the benefits-based approach.

STATE HIGHWAY COST ALLOCATION STUDIES

Table 1 presents the results and basic methods used in 85 state HCASs performed in the United States. Much of the data presented in the table were obtained from the 2005 Oregon Highway Cost Allocation Study conducted by ECONorthwest (2005). The data were updated based on the knowledge of the research team and survey responses. Based on these sources, the research team found 85 HCASs performed in 30 states. Undoubtedly, there are a small number of HCASs that have not been captured in Table 1. Indeed, the survey process demonstrated that there exists a general lack of institutional knowledge with respect to state HCASs in several states. This was discovered when on several occasions the respondent mistakenly indicated that no study had been done when the research team was aware of a previous study conducted in the respondent's state. The research team was able to assist the respondent in correcting the survey in some instances whereas in others, the research team was aware of but did not possess the study in question. Thus, the responses summarized in Appendix B may in some cases not capture the full extent of the state HCAS experience owing to the absence of institutional knowledge.

Table 1 identifies each state that has performed an HCAS (column 1) and the years in which the studies were completed (column 2). The column 3 results demonstrate that the Incremental and Federal Methods have historically been the principal methods used to conduct state HCASs. Each of these methods is commonly referred to under the umbrella of the cost-occasioned approach. The cost-occasioned approach determines cost responsibility based on the costs occasioned by various highway-user classes. This approach attempts to allocate cost responsibility based on the costs imposed by each class of highway users rather than simply allocating the costs based on relative use.

The percent of heavy-truck cost responsibility is presented in column 4. The historic results of state HCASs have varied widely with heavy-truck responsibility, from a low of 18.9% in the 1987 California HCAS to a high of 64.5% in the 1979 Florida HCAS. The heavy-truck share varies widely based primarily on the scope and type of expenditures included, but is also influenced by the proportion and type of heavy-truck traffic, the definition of the heavy-truck class [generally classified as vehicles weighing in excess of some weight threshold between 10,000-lb and 26,000-lb GVW (gross vehicle weight)], the methods used in the study, and the types of expenditures examined. The majority of the state HCASs conducted to date have allocated between 30% and 50% of the costs to the heavy-truck class.

The fifth column in Table 1 identifies the key allocators used in the state HCASs conducted to date. The allocator, or measure used to allocate costs to highway-user classes, is generally tied to either travel (e.g., VMT), the space vehicles take up on roads [e.g., passenger car equivalents (PCEs)], vehicle loads (e.g., ESALs), or a combination of these measures (e.g., ESAL-miles, ton-miles, axle-miles, and PCE-VMT).

Historically, state HCASs have focused on expenditures from state revenue systems and state tax systems; however, once the Interstate network was complete and federal and state funds became more interchangeable, recent studies have in most cases examined at least state and federal funds (Virginia and Wisconsin), whereas others have examined federal, state, and local funds in combination and in some cases separately as well (Arizona, California, Idaho, Indiana, Nevada, and Oregon).

TABLE 1
STATE HIGHWAY COST ALLOCATION STUDY METHODS AND RESULTS

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Arizona	1993, 1999, 2000, 2001, 2002, 2005	Federal	31.4% (1999)	VMT, Axle-Load, Gross Weight	State, Federal, and Local Funds Combined
Arkansas	1978	Incremental/Cost Function			
California	1987, 1997	Federal and Incremental	18.9%	ESAL-Miles	State, Federal, and Local Funds Analyzed Separately
Colorado	1981, 1988	Federal	37%	VMT, Truck-VMT, ESALs, Ton-Miles	
Delaware	1992, 1993	Federal and Incremental	20.33%	VMT, PCE-Miles, ESALs, Axle-Miles, Registrations	State and Federal Funds Combined Only
Florida	1979	Incremental	64.5%	VMT, ESALs, Axle-Miles, Registrations	State and Federal
Georgia	1979, 1982	Incremental	51.2% (1979)	VMT, GVW, ESALs, AMT	State and Federal
Idaho	1987, 1994, 2002	Prospective Cost-Occasioned	37.29%	VMT	State, Federal, and Local Funds Combined
Indiana	1984, 1988, 1989, 2000	Incremental/ Consumption	53.2%	ESAL	State, Federal, and Local
Iowa	1983, 1984	Federal	48.94%	ESAL, Ton-Miles, AMT, PCE, VMT	
Kansas	1978, 1985	Hybrid	41.85%	Number of Vehicles, VMT, AMT, Ton-Miles, PCE-VMT, ESAL-Miles	State Funds
Kentucky	1992, 1994, 1996, 1998, 2000	Federal	54.92%	VMT, ESAL-VMT, PCE-VMT, Axle-Miles	State and Federal Funds Combined
Maine	1956, 1961, 1982, 1989	Hybrid/Expenditure Allocation	35.6%	VMT, ESALs, PCE, Delphi, TMT, Standard Vehicle Equivalent	State and Federal funds
Maryland	1989				State and Local Funds
Minnesota	1990	Federal and Incremental	19.2%	VMT, Truck-VMT	

(*Continued on next page*)

TABLE 1
(*continued*)

State	HCAS Years Completed	Method	% Heavy Vehicle Cost Responsibility	Key Allocators	Types of Revenues Examined
Mississippi	1980	Incremental	36%	VMT, Truck-VMT	
Missouri	1984, 1987, 1990	Federal		Vehicle Size, Vehicle Weight, VMT	
Montana	1992, 1999	Federal	33%	VMT, ESAL-MT, AMT	
Nevada	1984, 1985, 1988, 1990, 1992, 1994, 1999	Modified Incremental	39.3%	ESALs, VMT, Axle-Miles, Ton-Miles	State, Federal, and Local Separately and Combined
New Mexico	1972				
North Carolina	1983	Federal		PCE, ESALs, VMT, Weight Axle-Miles	State and Federal Funds
Ohio	1982	Federal/Incremental		VMT	
Oregon	1937, 1947, 1963, 1974, 1980, 1984, 1986, 1990, 1992, 1994, 1999, 2001, 2003, 2005, 2007	Cost-Occasioned with NAPCOM for Pavement Costs (Since 1999)	34.1%	Congested PCE, VMT, Uphill PCE, Truck-VMT, Basic Vehicle VMT	State, Federal, and Local Combined for Cost Allocation Purposes but State Only for Revenue Attribution Purposes
Pennsylvania	1989, 1990	Federal/Cost-Occasioned			
Texas	1984, 1985, 1994, 2002				
Vermont	1990, 1993, 2006	Federal	25.7%	VMT, ADT, ESAL	State and Federal Funds
Virginia	1991, 1992	Federal	21.7%	ESALs, VMT, ADT	State and Federal Funds Combined
Washington	1977	Incremental			
Wisconsin	1982, 1992	Federal (1982)	31.7%	ESAL, VMT, PCE, Ton-Miles	State and Federal Funds Combined
Wyoming	1981, 1999	FHWA State HCAS Model	55.8%	VMT, Vehicle Size, Horsepower, Weight	

Adapted from ECONorthwest et al. (2005).

EQUITY FINDINGS IN STATE HIGHWAY COST ALLOCATION STUDIES

From 1982 to 2007, 26 states are known to have conducted HCASs. Table 2 presents the results of 22 of these studies with respect to the equity ratios for the heavy-truck class. The heavy-truck class is defined differently among states, but generally includes all vehicles weighing in excess of a certain weight threshold (e.g., 10,000 lb) and includes trucks, buses, and single-unit and combination trucks. The equity ratio is measured as the total tax payments attributable to a user class divided by its cost responsibility. To the extent that payments fall short of cost responsibility as measured through the HCAS, the equity ratio would be below 1.0. In 19 of the 22 studies referenced in Table 2, payments from the heavy-truck class fell short of cost responsibility. In three states (Delaware, Montana, and Oregon), heavy-truck payments were equal to or greater than their cost responsibilities (Stowers et al. 1999). A large part of the explanation of the results is tied to the differences in the state tax structures. Note for example that one of the three states (Oregon) in the over 1.0 equity ratio category had weight-distance taxes at the time of the study, and another (Delaware) collected a high proportion of its heavy-truck revenue fees from out-of-state based trailers.

Most state HCASs focus on equity between basic and heavy vehicles calculating equity ratios for each highway-user class. Resolution at this level, however, often fails to capture the full picture as it relates to equity within the state transportation tax structure. For example, the 1999 Arizona HCAS when applying the base HCAS model generated equity ratios ranging from 0.90% to 0.93% for buses, single-unit trucks, and combination trucks when examining the tax structure from a prospective view (1999 to 2003), but found that when historic data (1988 to 1998) were added to the calculation the equity ratios for buses fell to 0.67, single-unit trucks fell to 0.78, and the combination truck equity ratio was calculated at 0.89 (Carey 1999).

The 2000 Kentucky HCASs presents equity ratios for six highway-user classes (cars, buses, pickups and vans, light trucks, medium trucks, and heavy trucks) with equity ratios within the truck classes ranging from 0.90 for heavy trucks (registered vehicle weights in excess of 60,000 lb) to 1.52 for light trucks (Osborne et al. 2000). Oregon HCASs examine equity in a detailed manner with both cost responsibility and revenue attribution assigned in 2,000-lb increments above 8,000-lb registered gross weight. The most recent Oregon HCAS found that although the heavy-truck class as a whole met its cost responsibility, the equity ratio for the light truck class with declared weights between 10,001 and 26,000 lb was 1.26, whereas payments from operators of heavy trucks with declared weights of between 80,001 and 105,500 lb fell short of cost responsibility by 16.4% (ECONorthwest 2007).

TABLE 2
SUMMARY OF RESULTS OF STATE HIGHWAY COST ALLOCATION STUDIES (1982–2007): EQUITY OF TAX STRUCTURE FOR HEAVY VEHICLES

Equity Ratio for Heavy Vehicles	State and Year of Study
<0.60	Maryland (1982), Colorado (1988), Georgia (1991), Texas (1994), Nevada (1999), Vermont (2006)
0.60–0.80	Connecticut (1982), Missouri (1984), Indiana (1988), Minnesota (1990)
0.80–1.00	Wisconsin (1982), North Carolina (1983), Kansas (1985), California (1987), Maine (1989), Pennsylvania (1990), Arizona (1999), Kentucky (2000), Idaho (2002)
>1.00	Delaware (1992), Montana (1992), Oregon (2007)

Adapted from Stowers et al. (1999).

CHAPTER THREE

STATE OF THE PRACTICE

In reflecting on the history of HCASs conducted over the past 70 years, one point comes across most clearly: the motivation behind the HCAS is the achievement of equity. Historically, equity has been one of the most important principles driving tax policy, and has been considered when raising revenues and allocating funds for maintenance, capital improvements, operating programs, and services to the public. HCASs can aid in achieving equity-related objectives.

As noted in chapter one, an HCAS survey was distributed to all 50 state DOTs. A general conclusion from the survey responses is that state HCASs have reached a fairly stable condition. That is, there have been no major breakthroughs in research or methodology in recent years. Most states doing these studies are using some variation of the methods developed in the 1982 Federal HCAS, and most have been making gradual evolutionary improvements while achieving better efficiency in performing these studies.

RECENT DEVELOPMENTS IN HIGHWAY COST ALLOCATION STUDY METHODS AND SOFTWARE

Since the 1997 Federal HCAS, several states have made enhancements to their own studies based in part on the research and methodological improvements in that study. Although the FHWA commissioned the development of HCAS software and guidelines for states based on that 1997 HCAS, little has been done to market these products or to encourage states to continue to perform HCASs, and no technical assistance has been offered except for volunteer efforts by members of the team that developed FHWA's 2002 State HCAS Model. Some states have developed and applied simplified versions of complete studies, and some have conducted simple updates of previously completed studies.

Over the last decade since the completion of the 1997 Federal HCAS, few major changes in HCAS practice have occurred. The most significant recent activities have included:

- Completion of FHWA's work on development and refinement of NAPCOM.
- FHWA's development of NAPCOM into a model that can be relatively easily applied in state HCASs.
- FHWA's development of generalized state HCAS software building on the results of the 1999 Oregon HCAS and FHWA's work cited earlier.
- As part of FHWA's software development effort, analyses needed for inputs to the software for state HCASs (see chapter five).
- Vermont's successful use of the above software and guidelines with very minimal outside consultant effort (>$10,000).
- Oregon's continued analysis of numerous HCAS subjects in the issue papers prepared in its HCASs and its continued exploration of performing a full cost-based allocation study where the external or social costs that are imposed by the system are directly allocated to highway-user classes as opposed to the allocation of just highway expenditures.
- FHWA's continuing refinement of data collection programs by the states as a cooperative effort, resulting in far greater comparability of data among the states.

A consultant team working for the FHWA prepared an HCAS software package following completion of the 1997 Federal HCAS and the development of the first operational version of the package for the 1999 Oregon HCAS. The software consists of an Excel spreadsheet package intended for performing any state's HCASs. The package contains four spreadsheets—two main spreadsheets containing Visual Basic programs, a special visual analysis spreadsheet and a default data spreadsheet.

One of the main spreadsheets contains most of the data and the two programs necessary to perform the allocation of costs. The other main spreadsheet contains the programs that summarize the results of the cost and revenue allocations and produces various summary output tables using user-defined formats. After all required data are entered, each of the programs can be run by clicking on the buttons on the sheets at the locations shown in the tables of contents of each spreadsheet.

The third spreadsheet in the package contains a model derived from results of running the two main sets of programs. The model is designed to provide equity assessments of any special vehicle, such as a different truck configuration than currently allowed or a truck applying for an overweight permit. The fourth spreadsheet provides default data obtained from national sources or estimated from sources for each state. These default data can be used, with due care, to provide roughly half of the data required for application of the software.

The software package is supported by detailed documentation and a set of guidelines for preparation of all required inputs to the software (see chapter five). As a result of the recent Vermont HCAS, a few minor problems with this HCAS model have been identified and should be corrected. There is also a growing need to update the default database. Appendix C contains a letter from Bart Selle of VTrans that documents the technical problems with the FHWA State HCAS Model.

The Simplified Model for Highway Cost Allocation Studies in Arizona (Arizona SMHCAS) was designed to enable the Arizona DOT to update the state's HCAS report simply and in a cost effective manner. As noted in its completed survey, Arizona DOT representatives believe that if a state cannot find the budget to complete a comprehensive HCAS on a frequent basis (at least once every five years) it is better to use a simplified methodology rather than not doing a comprehensive study, because older HCASs are often "criticized or dismissed as obsolete given new traffic and new construction programs" (J. Semmens, personal communication, Jan. 2007).

The Arizona SMHCAS breaks highway expenditures into three categories: capacity-driven expenditures, strength-driven expenditures, and common costs. Both capacity-related and common costs under the Arizona SMHCAS are allocated to vehicle and weight classes based on relative shares of VMT. Capacity-related expenditures, however, are allocated based on urban VMT only, whereas common costs are allocated based on total VMT shares. One key element of the Arizona SMHCAS is that it treats urban and rural programs differently, with urban expenditures being allocated based on the view that these expenditures are driven by congestion and, thus, should be allocated based on relative shares of VMT. Expenditures on rural roadways are assumed to be driven by the need to provide pavements that are wide, thick, and strong enough to accommodate heavy-truck traffic. Based on this premise, rural costs are allocated based on vehicle axle loads driven per mile.

In 2001, contractors hired by the Oregon Department of Administrative Services converted the state's HCAS model, which was based on the State HCAS Model developed by FHWA, from an Excel-based spreadsheet model to a database model programmed in Access. The Access model was built with a dynamic structure that incorporated feedback loops enabling it to capture the impact that alternative tax rates would have on travel, vehicle ownership, and tax evasion (Jack Faucett Associates with ECONorthwest 2001). Although the model was constructed with this capability, evasion rate data along with price elasticity of demand data for vehicle purchases and highway travel were not developed or input into the model.

A model as complex as the one deployed in Oregon is not necessary to conduct an HCAS, because the feedback can be applied separately in any case where a study may seriously consider a major change in tax rates that would significantly affect highway use. States considering conducting an HCAS have a range of options, including using existing software such as the State HCAS Model prepared by the FHWA or developing a more simplified model similar to the Arizona SMHCAS.

VEHICLE CLASSES AND HOW THEY ARE DIFFERENTIATED

One key issue that is addressed in all HCASs is the determination of vehicle classes for the study. Highway cost allocation is strongly influenced by the weight and configuration of a vehicle. Damage caused to road systems is strongly influenced by vehicle weights and axle loadings. Ideally, HCASs would be designed to examine an extensive set of vehicle configurations and weight classes. In practice, vehicle categories, axle configurations, and weight classes are limited by data constraints (when selecting vehicle classes for analysis, the examiner must at a minimum acquire data that can effectively be used to attribute revenue, to estimate VMT, and to identify gross weights and axle loadings to each vehicle class), research budget limitations, and the inability of many transportation tax structures to effectively implement HCAS findings at a detailed level.

It is important to note that unless those performing an HCAS are considering recommendations for making changes in the tax structure, the selection of vehicle classes to be used in the study is often primarily driven by the state's existing tax structure. For example, the Oregon HCAS uses 2,000-lb gross weight classes primarily because the state's weight-mile tax rates are graduated in 2,000-lb increments. The availability of data and the state's tax structure are the two principal criteria used in determining vehicle classes. It is also important to note, however, that HCASs that include more detail in terms of vehicle class differentiation can aid in policy analysis and consideration of future changes to the existing tax structure even if modifications are not currently recommended.

After reviewing what various recent HCASs have done in defining vehicle classes, we will conclude this subsection with some additional elaboration of the issues relevant to establishing vehicle classes.

The 1997 Federal HCAS examined a broad spectrum of vehicle types and weight classes. Table 3 identifies the 20 vehicle types included in the 1997 Federal HCAS. In addition, these vehicle types were further examined according to weight categories in 5,000-lb increments. With the vehicle types and weight classes identified, the Federal HCAS could have examined vehicles in 600 categories or classes; however, there were many categories with no vehicles registered within them. For example, there are no 100,000-lb automobiles or 20,000-lb combination trucks registered in the United States. Ultimately, the Federal HCAS examined

TABLE 3
1997 FEDERAL HCAS VEHICLE TYPES

VC	Acronym	Description
1	Auto	Automobiles and motorcycles
2	LT4	Light trucks with 2-axles and 4 tires
3	SU2	Single unit, 2-axle, 6 tire trucks
4	SU3	Single unit, 3-axle trucks
5	SU4+	Single unit trucks with 4 or more axles
6	CS3	Tractor-semitrailer combinations with 3-axles
7	CS4	Tractor-semitrailer combinations with 4-axles
8	CS5T	Tractor-semitrailer combinations with 5-axles, two rear tandem axles
9	CS5S	Tractor-semitrailer combinations with 5-axles, two split (>8 feet) rear axles
10	CS6	Tractor-semitrailer combinations with 6-axles
11	CS7+	Tractor-semitrailer combinations with 7 or more axles
12	CT34	Truck-trailer combinations with 3 or 4-axles
13	CT5	Truck-trailer combinations with 5-axles
14	CT6+	Truck-trailer combinations with 6 or more axles
15	DS5	Tractor-double semitrailer combinations with 5-axles
16	DS6	Tractor-double semitrailer combinations with 6-axles
17	DS7	Tractor-double semitrailer combinations with 7-axles
18	DS8+	Tractor-double semitrailer combinations with 8 or more axles
19	TRPL	Tractor-triple semitrailer or truck-double semitrailer combinations
20	Bus	Buses (all types)

vehicles in 212 vehicle classes. The Federal HCAS could explore vehicle cost responsibility at such depth because the U.S.DOT was completing a comprehensive trucks size and weight study.

States have historically examined far fewer vehicle classes than what was considered in the 1997 Federal HCAS. Most but not all state HCASs differentiate vehicle classes based on both weight and configuration. For example, the 2006 Vermont HCAS examined 20 broad vehicle classes without consideration of weight: passenger cars, pickups and vans, 3 single-unit truck configurations, 14 combination-truck configurations, and buses. The 1999 Nevada HCAS classified vehicles only according to broad weight categories: basic vehicles weighing 10,000 lb or less and heavy vehicles weighing in excess of 10,000 lb.

Other states have established vehicle classes based on both axle configuration and registered vehicle weight:

- The 2007 Oregon HCAS modeled vehicle classes based on vehicle weights and number of axles in 2,000-lb increments.
- The 1999 Arizona HCAS considered five broad vehicle types and 23 weight classes.
- The 2000 Kentucky HCAS used both vehicle and weight categories to establish 17 vehicle classes: motorcycles, cars, buses, and 14 truck classes differentiated solely by registered or declared weight.
- The 2002 Idaho HCAS covered five vehicle types (autos, pickups, buses, single-unit trucks, and combinations) spread over 9 weight classes.

Studies can also differentiate between vehicle classes based on fuel type (e.g., gasoline, diesel, alternative fuels or hybrids) and on treatment in the tax code (e.g., full-fee paying, partial-fee paying, and exempt).

To elaborate and summarize, vehicle classes are generally defined in any HCAS with the following considerations:

- From a perspective of distinguishing vehicles by cost responsibility: (1) operating axle weights of vehicles, (2) gross weights of vehicles, (3) miles operated, and (4) differences in the streets and highways on which vehicles operate.
- From a perspective of distinguishing vehicles by user payments made: (1) fuel economy, (2) registered weight class and other vehicle class differences, and (3) fee exemptions and reduced fee classes of special vehicles, such as publicly owned vehicles, out-of-state-based vehicles, and vehicles used in particular industries or vehicles providing special services.
- Existing vehicle registration classes.

- The possible need to subdivide any vehicle registration classes into two or more subclasses because of any of the aforementioned cost responsibility considerations.
- Defining vehicle classes in one way for analysis of cost responsibility and in another way for revenue attribution: it is important to have a good way of applying conversions from one class to the other or to summarize categories of vehicle classes for reporting results and estimating equity ratios.

FUNCTIONAL CLASSES OF ROAD SYSTEMS EXAMINED IN HIGHWAY COST ALLOCATION STUDIES

The determination of the functional classes of road systems examined within an HCAS is important because higher order systems (e.g., Interstates, other freeways and expressways, and other principal arterials) are designed to higher standards to withstand the punishment of heavy axle loadings and high traffic levels. Therefore, the attribution of cost responsibility is inextricably linked to the design standards of the roadway systems where both the miles of travel occur and the construction and maintenance expenditures are made. The following is a list of the standard 12 functional classes designated by AASHTO in cooperation with FHWA.

- Rural
  - Interstate
  - Other Principal Arterials
  - Minor Arterials
  - Major Collectors
  - Minor Collectors
  - Local
- Urban
  - Interstate
  - Other Freeways and Expressways
  - Other Principal Arterials
  - Minor Arterials
  - Collectors
  - Local

Historically, these 12 functional classes have served as the standard in terms of the treatment of functional classes of road systems in HCASs. The 12 functional class system was used in the 1997 Federal HCAS, 1999 Arizona HCAS, 2000 Kentucky HCAS, and the 2007 Oregon HCAS, although some other recent HCASs have compressed these functional class road systems into a smaller number of categories for reporting purposes (1999 Oregon HCAS and 1999 Nevada HCAS).

The designation of highway functional class between rural and urban is another important distinction. The distinction of rural versus urban has taken on additional significance in recent Arizona HCASs. The Arizona SMHCAS simplifies the cost allocation procedure by assuming that expenditures on urban roads are driven by congestion and should be allocated based on relative shares of VMT, whereas expenditures on rural roadway systems are driven by the strength requirements caused by heavy truck traffic and, therefore, should be allocated based on vehicle axle loads and mileage.

SELECTING APPROPRIATE COST ALLOCATORS

Each element of a state HCAS relies on some measure that can be quantified and used to allocate costs to various classes of highway users. Under the Incremental Method, the recognition that roads are built wider and thicker to withstand the loading of heavy trucks led to the allocation of a certain portion of roadway width and depth solely to heavy trucks. In recent years, however, more comprehensive models, including NAPCOM, have been developed to assign cost responsibility to vehicle users based on a more complete understanding of the influence of vehicle traffic, environment, and other factors on pavement deterioration. These models predict the impact that highway use will have on pavement damage based on empirically established relationships between axle weights and pavement damage, and assigns cost responsibility based on these established allocation factors.

In the absence of a more comprehensive pavement model, some states have historically used more straightforward measures that are designed to vary in proportion to the damage caused to the roadway system by vehicle classes. These allocators include:

- Axle Miles of Travel (AMT)—VMT multiplied by the number of axles. Because trucks generally have more axles than cars, sports utility vehicles (SUVs), or pickups, their share of the total AMT on any given highway system will be about double their share of the VMT on that system.
- Axle Weight or Axle Load—The gross load carried by an axle.
- Ton-Miles—VMT multiplied by tonnage.
- Equivalent Single-Axle Loads and Equivalent Single-Axle Load Miles—The pavement stress imposed by a single axle with an 18,000-lb axle load is termed one ESAL. ESAL-miles are equivalent single-axle loads times miles traveled.

These allocators have been used extensively at the state level to assign specific wear-related costs to highway-user classes. For example, the 2007 Oregon HCAS, while using a comprehensive HCAS model, assigns striping costs based on axle-miles of travel (ECONorthwest 2007). Roadway striping deteriorates as a result of friction of tires wearing away the paint on roadways. Thus, the number of axle-miles is used as a proxy for the number of times contact is made between vehicle tires and roadway striping. The 1999 Arizona HCAS allocates the costs associated with the extra roadway thickness required to accommodate heavy-truck traffic based on

axle loadings (*1999 Update of the Arizona Highway Cost Allocation Study* 1999).

Bridge costs have historically been allocated to highway-user classes based on the size and weight of the vehicles crossing the structures. When assigning these costs, two key issues are:

1. The definition of increments used in the incremental analysis of bridge cost responsibility and the methods used to assign vehicles to those increments.
2. The methods used to allocate costs among increments, including the determination of load and non-load portions of bridge costs.

Bridge costs are often stratified into three categories: new bridges, bridge replacements, and bridge rehabilitation. The costs associated with new and replacement bridges have historically been allocated in many studies based on an incremental analysis of the costs of constructing bridges using different design loadings. This approach was used in the last two federal HCASs and several state HCASs. These loadings are based on hypothetical vehicles for which stresses in the load-bearing members of bridges are calculated and compared with permissible stress levels. As loadings become heavier, the size of bridge members, and consequently bridge costs, must be increased to remain within permissible stress levels.

When allocating bridge rehabilitation costs, load- and non-load-shares are determined. Bridge rehabilitation addresses the needs to both improve its structural and functional condition. The non-load share of bridge rehabilitation costs is largely allocated to all vehicles based on relative shares of VMT. This allocation procedure is based on the principle that vehicle wear drives rehabilitation costs. The load share of rehabilitation costs is often allocated to heavy-truck classes based on some measure that accounts for the additional stress placed on bridges by heavy vehicles, such as ESAL-miles or heavy-truck VMT (Stowers et al. 1998). Issues relating to the allocation of pavement and bridge costs are examined in more detail in chapter five.

Historically, the costs associated with new roadways were allocated based on an incremental analysis of the additional thickness and depth required to sustain heavy trucks. In recent years, however, the costs of constructing new roads in urban areas have been treated as investment decisions relating to the tradeoffs between congestion and roadway expenditures. Thus, new facilities in urban areas are often viewed as designed to relieve congestion levels on existing facilities. With this view in mind, state HCASs are increasingly allocating capital costs in urban areas based on the contribution of each highway-user class to congestion. From an empirical standpoint, the ideal state would exist if state HCASs examined the costs associated with congestion (including wasted time and fuel, emissions, and noise), states implemented highway-user tax structures that taxed on a marginal cost rather than average cost basis, and those fee structures could be used to address cost responsibility. The economic principles involved have been addressed in the 1997 Federal HCAS and recent Oregon studies.

In the absence of this preferred set of circumstances, most states have found proxy allocators used to attribute most capital costs largely based on some measure of travel. In the 1999 Arizona HCAS, an additional distinction was made in the simplified model between urban and rural capital costs with urban costs assumed to have been driven by congestion and allocated based on relative shares of VMT. The base Arizona HCAS model in the 1999 Arizona HCAS used axle loadings to assign cost responsibility for the additional pavement thickness required to accommodate heavy-truck traffic. The 2007 Oregon HCAS assigned responsibility for the base increment cost based on a measure of the space that vehicle classes take up on roadway systems during congested periods. This allocator is referred to in the Oregon studies as congested PCE VMT. The PCE factor is an appropriate allocator because congestion is driven by the space that vehicles occupy on the road system, not simply the number of vehicles or the total number of miles traveled. Heavy trucks are larger and require more braking and acceleration distances to operate safely on road systems and, therefore, have a greater PCE factor than lighter, smaller vehicles.

There are elements of any transportation agency budget that have no clear relationship to specific vehicle characteristics. These costs include planning and administrative overhead costs. These costs are generally allocated based on either an assignment of responsibility to a specific highway-user class or some general measure of VMT. When considering the allocation of costs to a specific user class, an appropriate example would be the allocation of expenses tied to motor carrier enforcement. These costs would not be incurred in the absence of heavy-truck traffic. Therefore, costs associated with motor carrier enforcement are generally allocated to heavy-truck classes based on the relative shares of VMT for each class of heavy trucks.

COST ALLOCATION IN A MULTIMODAL ENVIRONMENT

Recent developments in federal policy have served to increase the flexibility in the application of federal-aid funds and encourage intermodalism. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) encouraged the development of a broad multimodal system through incorporating modes into a National Intermodal Transportation System. In turn, some have argued for a broader consideration of modes in the cost allocation process. To proponents of intermodalism, the exclusion of other modes serves to promote an incomplete understanding of equity.

One study examined the policy implication of applying cost allocation across all modes, examined the pros and cons

of a multimodal approach, and presented recommendations related to the treatment of alternative modes in transportation cost allocation (Wheeler 1996).

The arguments in favor of a multimodel approach to cost allocation identified in the study included:

- An application of transportation cost allocation in a multimodal environment would encourage the emergence of a broader view of the transportation system.
- Multimodal cost allocation would enhance uniformity and coordination when spending decisions are made.
- Highway users generate external costs (air pollution, congestion, noise) that are typically not addressed in HCASs, but impact society and other modes of transportation.
- Highway users benefit from the multimodal transportation systems that support the road network.

Arguments against the multimodal approach cited by the author were tied to the uncertainty associated with the multimodal approach and its inability to be used to directly set highway-user charges. The author also noted the complications associated with the inability of most other modes (e.g., rail and public transit systems) to recover operating costs through user charges.

The author concluded that there is a need to move toward a broader application of transportation cost allocation; however, more research is needed to implement such a strategy. Required research proposed by the author included:

- A detailed review of multimodal economics;
- The development of a mode-by-mode approach to transportation cost allocation; and
- Examination of the feasibility of extending transportation cost allocation to all levels of government, including federal, state, and local government.

METHODOLOGIES FOR REVENUE ATTRIBUTION

The process of attributing revenues to highway-user classes is an essential step in any HCAS. The equity ratios created for each vehicle class serve as the principal findings of state HCASs. Although most attention in the literature focuses on cost allocation, revenue attribution has an equal weight in determining the outcome of an HCAS. Revenue attribution results in producing the numerator over the cost allocation denominator in any equity ratio. Guidelines for performing revenue attribution are contained in a section of chapter five.

States have historically focused on state revenue sources. Reasons cited for focusing on state revenue sources include the historic inflexibility with respect to how federal funds could be used and the inability of states to make adjustments to the federal tax structure. However, because of the flexibility built into the federal-aid program in recent years, many recent studies have included federal, state, and local revenues in the attribution process (Arizona, California, Idaho, and Nevada), and others have included state and federal revenues in the attribution process (Delaware, Kentucky, Vermont, Virginia, and Wisconsin). Maryland attributes state and local revenues to highway-user classes. Oregon has established a unique approach. In recent Oregon studies, the numerator of the equity ratios has included only state revenues, but the denominator has included both state and federal expenditures. The resulting imbalance is corrected by converting the equity ratios to adjusted equity ratios by expressing the ratio as shares of total revenue divided by shares of total expenditures, as is commonly done in state HCASs (see further discussion in the levels of government section of chapter five).

The 1997 Federal HCAS and virtually all state HCASs allocate expenditures and attribute revenues to the various user classes for a future time period based on adopted programs and short-term program and revenue forecasts. Most states focus on programmed state transportation improvement program (STIP) expenditures projected over a future time period. Traffic and other data are also projected forward for the same future years.

The logic behind this approach is that forecast data provide a more accurate description of the changing characteristics of demand for travel and expenditures based on changing conditions. For example, constrained budgets and the normal deterioration of a state's roads and bridges could signal a shift in public investment from capacity expansion to operation and maintenance of existing highways. Historical data would not adequately reflect this trend. To get a better picture of expenditures, a state may choose to consider past expenditures (e.g., 2 to 4 years) as well as future program costs, while being cautious in the treatment of one-time large expenditures. The time periods considered in a number of recent studies are presented in Table 4.

Similar to the 1997 Federal HCAS, state HCASs generally attribute motor fuel tax revenues based on estimates of travel in the state being examined and motor fuel economy.

TABLE 4
RECENT HCAS STUDY TIME PERIODS

Study	Study Time Period
Arizona (1999)	1999–2003
Idaho (2002)	2001–2005
Federal (1997)	2000
Nevada (1999)	1998–1999, program expenditures based on 1999–2008 STIP
Oregon (1999)	SFY 2000—SFY 2001
Oregon (2007)	SFY 2008—SFY 2009
Vermont (2005)	2005

Miles-per-gallon estimates are generally obtained through industry surveys, including the Vehicle Inventory and Use Survey (VIUS), or through the default values contained in the State HCAS Model prepared for the U.S.DOT. For states with weight-distance taxes (Kentucky, New Mexico, New York, and Oregon), the revenue attribution process is more transparent as distance-based taxes are graduated to reflect the declared vehicle weights typically examined in state HCASs.

Attribution of registration fees, particularly those of International Registration Plan apportioned vehicles, can be extremely complicated at the state level, depending on the quality of the state's registration fee and related database. The principal issue that must be addressed is how to convert payments by user classes that are defined by registration fee schedules to user classes examined in the HCAS. For example, the revenue attribution process may require conversion of registration fees based on registered gross weight to data based on vehicle body type and axle configuration. Some states have constructed complex matrices to perform this conversion. For example, a matrix prepared for the state of Pennsylvania relied on data provided through VIUS, the International Registration Plan, and special studies conducted at the state level (Jacoby 1990).

Table 5 presents guidelines used to conduct a detailed revenue attribution process in Kentucky (Osborne et al. 2000). In

TABLE 5
GUIDELINES FOR THE ALLOCATION OF HIGHWAY-USER REVENUE TO VEHICLE CLASSES IN KENTUCKY

Element	Vehicle Class	Basis
Fuel Tax		
Heavy vehicle surtax	Trucks over 59,999 lb	Revenue estimates from VMT, rates of fuel consumption, and tax rates
Carrier surtax	Trucks over 26,000 lb	See above
Normal use	All	See above
Federal Excise Tax	All	See above
Vehicle Registration & License		
Cars	Cars	100%
Buses	Buses	100%
Motorcycles	Motorcycles	100%
Trucks	Trucks	Revenue estimates from number of registered trucks and registration fees (with adjustments for farm, exempt, and 6,000-lb trucks)
Apportioned trucks	Trucks	Number of ID cards
Truck ID cards	Trucks	Number of ID cards
Truck permits	Trucks	Number of ID cards
Other	All	Vehicle-miles
Miscellaneous	All	Vehicle-miles
Operators License	All	Vehicle-miles
Commercial Driver's License	Trucks over 22,000 lb	Vehicle-miles
Usage Tax		
Buses	Buses	100%
Other vehicles	All excluding buses	As reported
Federal trucks and trailers	Trucks over 33,000 lb	Vehicle-miles
Road Tolls	All	Toll collection receipts
Other Motor Carrier Taxes		
Weight distance	Trucks over 59,999 lb	Vehicle-miles
Extended weight	80,000-lb trucks	100%
Federal use	Trucks over 54,999 lb	Vehicle-miles
Other Federal Taxes	All	Vehicle-miles

Kentucky, the primary sources of revenue include fuel taxes, registration and license fees, usage taxes, road tools, other motor carrier taxes, federal taxes, and miscellaneous taxes and fees. This table demonstrates how highway-user fees are attributed to each vehicle class. For example, the Kentucky weight distance tax is allocated to trucks weighing in excess of 59,999 lb based on VMT. The regular Kentucky motor fuels tax is allocated to all highway-user classes based on a revenue analysis that considers VMT, rates of fuel consumption, and tax rates.

TREATMENT OF DIVERSIONS OF HIGHWAY-USER REVENUES TO OTHER USES

States have varied in their treatment of diversions of highway-user revenues to other uses. Some HCASs have identified the diversion of highway-user revenues to other uses but have eliminated them from consideration, whereas others have attempted to judge each diversion based on its relative merit. For example, most but not all states consider the highway patrol as an essential element of the highway program and allocate these costs accordingly (Idaho Department of Transportation 2002).

The 1997 Federal HCAS allocated expenditures of highway-user revenues on mass transit. The principle underlying this approach was that expenditures on mass transit facilities represent a form of congestion management and, therefore, should be allocated to highway users. Thus, mass transit expenditures were allocated to automobiles, pickups, and vans in proportion to VMT on higher-order urban highways. It is worth noting that practitioners interviewed for this study indicated that because heavy-vehicle classes also benefit from congestion-relieving transit investment, it would be more appropriate to allocate these costs according to congested PCE. It is also worth noting that not all forms of transit investment ease congestion. For example, although the Central Phoenix/East Valley Light Rail Project is expected to reduce VMT by four-hundredths of one percent in the region, vehicle speeds are expected to drop by one-tenth of a mile per hour in the region and one-fifth of a mile per hour in the corridor served by light rail (*Final Environmental Impact Statement* . . . 2002). This counterintuitive result is expected to occur because the light rail will be constructed in an existing roadway (thus reducing roadway capacity), trains will be given signal preemption rights that will disrupt signal synchronization with vehicular traffic, and train tracks are expected to block direct access to many driveways and side streets along the route.

Other HCASs exclude these diverted revenues. For example, the 1999 Nevada HCAS identifies the total value of diverted higher-user funds at the federal, state, and local levels in Nevada but does not allocate them noting: "Since the purpose of highway cost allocation is to identify whether different vehicle classes are contributing in proportion to their cost responsibility, only the taxes that come from highway users and are used for highways are included in our study" (*1999 Highway Cost Allocation Study* 1999). The 2005 Vermont HCAS also focuses exclusively on state expenditures to build and maintain roads (Selle 2006). Oregon has avoided this issue entirely by virtue of its constitutional requirement that all highway-user revenue be used for the construction, rehabilitation, and maintenance of roads in the state.

The 1994 Texas HCAS excluded the impacts of state highway-user taxes that had been used to fund education programs in the state and federal funds used on mass transit projects (Euriat 1994). In 2000, however, a study sponsored by the Texas DOT recommended exploring scenarios in the next Texas HCAS that would allocate all revenues regardless of their use (Luskin et al. 2001).

EXPERIENCE IN SELECTED STATES

Brief highlights of HCAS work by 11 selected states are summarized in this section. These states have been selected either because (1) they have been leaders in the field, (2) the amount of work they have done, or (3) they have performed work that may be of significant interest to other states that may want to borrow from what they have learned or use the results of their work directly or indirectly.

Arizona

Arizona is one of four states that had conducted five or more HCASs and responded to the survey. Each HCAS was completed within the last 14 years, with the last being completed in 2005. It completed a comprehensive study in 1992 to 1993 that included all of the currently recommended analyses and methods, with the exception of some refinements based on the 1997 Federal HCAS.

In 1999, Arizona developed and applied a simplified method based on the 1993 study and then applied it again twice over the next two years. The amount of effort involved was reduced by an order-of-magnitude. The output of both the simplified and traditional Arizona HCAS model is presented in Table 6. As shown, the results are consistent between the two models for the auto and bus classes. However, the simplified model generated results that varied significantly from the Arizona HCAS model for pickups and SUVs (20.7% difference), single-unit truck class (56.7% difference), and combination trucks (14.8% difference). When studying broader vehicle classes (e.g., basic vehicles versus heavy trucks), the results are fairly consistent. See the last section of chapter five dealing with simplified models for further discussion of the implications of these observations and how improved models of this type might be developed.

California

California has conducted only two HCASs (1984 to 1987 and 1995 to 2000), but both made important contributions—the first primarily in terms of principles and methodology and the

TABLE 6
EQUITY RATIOS AND COMPARISON OF SIMPLIFIED MODEL TO ARIZONA HCAS RESULTS

Vehicle Class	Equity Ratios	
	Simplified Model	Arizona HCAS Model
Autos	1.33	1.30
Pickups/SUVs	1.45	1.74
Buses	0.93	0.90
Single-Unit Trucks	1.41	0.90
Combination Trucks	0.81	0.93
Total	1.20	1.20

Source: *1999 Update of the Arizona Highway Cost Allocation Study* (1999).

second in terms of demonstrating the value of organizing an HCAS so that it can be open to rapidly changing circumstances.

The 1984 to 1987 study was one of the first to be initiated after publication of the 1982 Federal HCAS report and the subsequent national dialog about the impact of that benchmark study. In performing that study the California DOT made a major commitment to doing the study in a manner that was fully responsive to the 1982 federal study in terms of both economic concepts and the logic behind each of the technical advancements of the 1982 study.

Some of the contributions of the 1984 to 1987 study went beyond the federal study in defining economic principles in operational terms and implementing them:

- Highway-user payments should be defined to include all types of payments that are unique to the use of highways, regardless of where or how those revenues are spent.
- Highway expenditures and future costs should be defined to include all expenditures regardless of the source of funds for the expenditures and regardless of which agency is responsible, and all costs that are public responsibility regardless of whether they have yet been formally adopted or budgeted.
- Expenditures for other modes of transportation (primarily transit) should be included if they are publicly recognized as being of substantial benefit to highway users, either in terms of congestion reduction or conservation of highway capacity for future growth.
- Each level of government should be analyzed separately so that results can be presented in the most flexible manner, either separately or in any combination.
- Careful attention should be given to defining what expenditures are properly considered part of the analyses for each level of government. For example, state aid to local governments is part of state programs and federal aid to state or local governments is part of the federal program.
- A credible HCAS cannot be done for any state's local governments without use of a specially designed survey of local governments. Such surveys should be built around existing data recently reported by local governments.

Other technical contributions of the 1984 to 1987 California HCAS included:

- Complete adaptation of the 1982 Federal HCAS methods for application at the state level, reflecting the differences in available databases and differences in a variety of technical methods used in pavement and bridge design.
- Development of new operational procedures for crosswalks between (1) expenditure databases and new data developed for expenditures for cost allocation categories such as new pavements, pavement rehabilitation, pavement maintenance, similar breakdowns for bridge work, grading and drainage, etc. (see Table 11 in the guidelines section of chapter five), and (2) registered weights and operating weights. A significant aspect of these efforts involved analyses of detailed data from project files, weigh-in-motion (WIM) data, and data from weigh stations.
- Development of well-defined criteria for defining vehicle classes.
- Development of procedures for distinguishing full-fee paying vehicles and exempt, partially exempt, or special-fee-paying vehicles for each vehicle class.
- Development of procedures for revenue attribution that provide reliable estimates of total taxes and fees paid for each vehicle class for both full-fee-paying vehicles and others.

In developing these procedures, California was able to avoid having to deal with various complex issues that are not important in terms of basic cost allocation principles or equity concerns. These include issues that some states have struggled with, such as the amount of evasion there is for various taxes and fees and how to deal with tax subsidies that all legislatures have created for various categories of vehicles.

The improvements made in the 1984 to 1987 California HCAS have been used and improved on in subsequent HCASs in California, Vermont, Arizona, Idaho, Minnesota, and Oregon, and in the State HCAS Model developed for FHWA.

The 1995 to 2000 California HCAS built on and refined the work of the earlier study, and was noteworthy not for the types of improvement advances described earlier, but for two unique aspects that differentiated it from all other state HCASs.

The first is how the study dealt with a complex set of impacts that were central to the purpose of that study. Because of recent changes in federal law, California had to make basic changes in how weight fees were being collected on both power units and trailers or risk a loss of more than $100 million per year. The challenge California faced was how to make

these changes and eliminate most trailer fees for commercial vehicles so that (1) fees would bear the closest possible match with cost responsibility of vehicles owned and operated by the many different classes of industry in the states, and (2) how to best select from a wide range of options available for achieving this in a way that did not unduly burden any segment of the trucking industry or the general public.

To meet this challenge, a very user-friendly spreadsheet was developed for California (similar in concept to the one described in the weight fee subsection of the guidelines in chapter five) that permitted the project team, California DOT staff, and any interested participant from industry to easily develop and evaluate proposed alternatives. This facilitated more than a year's worth of technical work and dialog among all interested parties before the HCAS report and recommendations were prepared in 1999.

The other unique aspect of the 1995 to 2000 California HCAS was a completely unanticipated legislative action that fundamentally changed California's highway-user tax structure. The legislature decided to phase out and totally eliminate the state's $1.5 billion per year vehicle license fees (an ad valorem annual fee on all vehicles including trailers).

California decided to have its HCAS consultant work with the department of motor vehicles (DMV) to develop and evaluate alternatives for increasing other fees on a schedule that would create revenue neutrality at each step in the phase-out period for the vehicle license fees. The project team had to adopt the findings, database, and methods developed for that HCAS to develop and evaluate alternative fee schedules for these phases based on HCAS principles, the revenue neutrality requirements, and a requirement that this revenue neutrality be maintained for each agency that received a formula share of all highway-user revenues. The required set of fee increases was developed in consultation with the concerned agencies and was submitted to the legislature in 2000 (Sydec Inc., et al. 1999).

Idaho

Idaho has conducted two relatively recent HCASs—in 1994 and 2002—and several years ago made an attempt to apply FHWA's State HCAS Model but found that it required greater information technology (IT) expertise than was available at the time. Based on that experience, the Idaho Transportation Department recently undertook a third HCAS using FHWA's State HCAS Model with the assistance of two Washington State Economists. Although this study was effectively completed in 2007, the results have not been published.

Idaho is an appropriate state in which to conduct a second low-cost test of FHWA's State HCAS Model, because it has the following advantages:

- An interest in periodic performance of HCASs;
- Good databases for most of the inputs required;
- A fairly small central office staff used to working together cooperatively without the need to create special task forces with formally delegated powers; and
- Recent experience in conducting two HCASs.

Indiana

Indiana is one of three states known to have experience with HCASs that did not respond to the survey. Our only source of information about this experience is from the website of the Joint Transportation Research Program of Purdue University and the Indiana DOT and publications by the Director of the Joint Transportation Research Program, Professor Kumares Sinha and others. The 1988 HCAS used the incremental approach, employed extensive data sets, and used numerous allocators, including ESALs, to apportion costs among attributable and non-attributable classes of costs (Sinha et al. 1989).

Kentucky

Kentucky is the second of the four states responding to the survey that had conducted five or more HCASs, and like Arizona had conducted all of them in recent years (every two years from 1992 through 2000). The studies were done as an initiative of the Kentucky Transportation Cabinet (KTC), and had been effective in calling attention to the inequities of the tax structure.

According to the KTC's survey responses, recent HCASs were criticized for their treatment of a small number of methodological issues. The principal issue revolved around the low tax rate for the weight-distance tax relative to heavy-truck cost responsibility. The explanation for the decision by KTC to stop conducting HCASs on a regular basis is not that the tax burden would be too much with an increase in weight-distance tax rates, but that "the evasion was too high." Evidence to support this conclusion came from an analysis of evasion that compared actual tax collections with an estimate of tax liability based on VMT estimates for vehicles weighing in excess of 59,999 lb. Based on the outcome of this analysis, weight-distance tax liability was estimated at $86.6 million as compared with actual tax receipts of $70.2 million (Osborne et al. 2000). The argument behind this decision is that although an increase in weight-mile tax rates would bring about equitable payments from heavy-truck classes as a whole, tax payments would exceed the cost responsibility calculated for the majority of the motor carriers who comply with current tax systems. Further, the argument was advanced that if the KTC reduced evasion associates with weight-mile taxation, heavy-truck payments would equal cost responsibility under the current system and no adjustments to tax rates would be necessary.

This decision is one that might have benefited from the findings of the Oregon Weight-Mile Tax Study. The same tax evasion issues had been raised, and Oregon DOT's response

was to investigate the reality of the claim. The study found that evasion of the weight-mile tax was not excessive in comparison with evasion rates for other taxes and fees. The study also examined the trade-off between the weight-mile tax evasion rate and the level of enforcement and concluded that, although the level of enforcement was somewhat below the optimal level (i.e., the enforcement level of effort that would result in the lowest sum of enforcement costs and revenue lost as a result of evasion), the level of evasion was within an acceptable range at 3% to 7% (Cambridge Systematics et al. 1996). The authors of the report recommended a detailed program of increased enforcement that would both reduce evasion and increase the cost-effectiveness of the enforcement program.

Maine

Maine DOT has completed at least four HCASs—in 1956, 1961, 1982, and 1989 (*Maine Highway Cost Allocation Study* . . . 1989). Maine's work in at least the last of these studies is of interest because the authors of this work developed original approaches, while generally following the best thinking regarding basic principles of cost allocation. The 1989 Maine HCAS was required by legislation designed to improve equity in the state.

The 1989 study examined a small number of expenditure categories: highway construction, maintenance, bridge construction, local assistance, and other outlays. The 1989 Maine HCAS used standard approaches for overall study design (e.g., cost-occasioned approach and allocating actual expenditures as opposed to costs). It did, however, use some unusual allocators and approaches for attributing costs, including VMT, ESALs, PCEs, truck miles traveled, standard vehicle equivalent, the Delphi method, overhead, and other allocators. The Delphi method, as applied in the Maine HCAS, allocated some expenditures based on the judgment of maintenance experts. The study also used miscellaneous allocators such as fuel consumption and the number of registrations by vehicle class.

Minnesota

The Minnesota DOT is believed to have conducted only one HCAS (1989 to 1990) using an improved version of the interlinked set of spreadsheets developed and applied for Vermont. When compared with the earlier Vermont study, the Minnesota study incorporated more detailed analysis of revenues, expenditures, pavement designs and types; more detailed program categories and classes of highways; and more detailed analysis of expenditures by local governments.

The study finished with two sets of analysis requested by legislative staff:

1. An evaluation of specific alternative changes in tax structure.
2. Analyses of special classes of vehicles that have, or potentially might have, reduced tax rates based on revenue contributions beyond their cost responsibility (*Result of the Minnesota* . . . 1990).

Nevada

Nevada has completed six HCASs and is the third of the four states that completed five or more HCASs and responded to the survey. Nevada HCASs were conducted in 1984, 1988, 1990, 1992, 1994, and 1999.

An outside audit was conducted in 1995 in response to questions and comments by stakeholders and the legislature. The audit included a thorough review and assessment of the procedures and analyses used by the Nevada DOT in the first four Nevada studies, resulting in recommendations for refinements that were incorporated in the 1999 study procedures (Sydec 1994).

Oregon

Oregon is the fourth of the four states that completed five or more HCASs. It conducted the first HCAS (called "cost responsibility" studies in that state until recently) in 1937 and has conducted studies fairly routinely ever since, having completed its fifteenth in 2007—more than twice as many as any other state.

Oregon has been the developer of most of the basic principles that have come to be widely accepted in this field. It has been among the first to adopt the results of research performed by the FHWA and others and adopt new national HCAS methods for use at the state level.

The 1999 Oregon HCAS was the first state study to adopt FHWA's new NAPCOM for allocation of pavement costs and was the first to make use of the results of other research and methodology from the 1997 Federal HCAS. The software developed for the 1999 Oregon study was the first to use Excel's new Visual Basic programming language, and it formed the basis for FHWA's subsequent development of the generalized HCAS model developed for use by other states, as described previously.

Recent Oregon studies have also included a rather comprehensive set of issue papers covering most of the common choices facing complex state HCASs. The 1999 Oregon HCAS issue papers included:

- Pavement issues
  - Alternative methods for allocating pavement cost responsibility,
  - Load and non-load-related damage shares for pavement costs,

  - Allocation of load-related portion of pavement and shoulder costs,
  - Use of AMT as an allocator for selected costs,
  - Reliability of data supporting pavement damage relationships, and
  - Appropriate environmental factors for allocation of pavement costs.
- Bridge issues
  - Definition of increments,
  - Cost allocation methods,
  - New bridges and bridge replacement,
  - Bridge rehabilitation costs, and
  - Bridge maintenance.
- Width-related cost issues
- Other attributable cost issues
  - Allocation of costs of capacity improvement projects,
  - Allocation of right-of-way costs,
  - Allocation of climbing lane costs, and
  - Allocation of rest area costs.
- Common and residual cost issues
- Other cost elements and time frame issues
  - Exclude or include congestion and other external costs,
  - Use of expenditure versus cost-based approach,
  - Use of historical versus forecast data, and
  - Treatment of federal and local revenues and expenditures.

Since the 1999 Oregon study, there has been a shift in emphasis in cost allocation procedures from use of engineering and axle weight allocators toward vehicle use allocators. Achieving an appropriate balance between the engineer's and the economist's perspective has, in effect, become a new HCAS policy issue as a result of Oregon's recent experience.

Texas

The Texas HCASs have employed innovative techniques to conduct highway cost allocation. For example, the 2002 Texas HCAS examined the climatic factors that affect the durability of highways. The study used numerous climatic factors to differentiate local climates, and based on a statistical analysis, found the following factors could be used to establish the relationship between climate and pavement deterioration: Thornthwaite Index (index of moisture), average winter temperature, total freeze-thaw cycles in one year, and total precipitation or rainfall. This analysis was used to establish five relatively homogeneous climatic regions within the state. Establishing these regions affected how costs associated with the deterioration of pavement were allocated among highway-user classes.

Four major cost components were considered for allocation in the 2002 Texas HCAS:

1. Pavement construction costs (including reconstruction),
2. Pavement rehabilitation and maintenance costs,
3. Bridge costs, and
4. Common costs.

The 2002 Texas HCAS allocates bridge costs based on the modified incremental approach. It allocates common costs proportionally based on VMT. To allocate flexible and rigid pavement construction, rehabilitation, and maintenance costs, the study uses five allocation methods:

1. Generalized method—Allocates costs based on a hypothetical facility specially designed for groups of vehicle classes, with costs for the base facility allocated based on VMT and the load-related costs allocated to vehicle classes based on the optimal design for each combination of vehicle classes, highway type, and climatic region.
2. Proportional based on ESALs.
3. Modified incremental analysis—Allocates costs incrementally, with some cost elements allocated to specific vehicle classes and others allocated to multiple vehicle classes.
4. Variable lanes approach that allocates costs based on the lanes required for different classes of vehicles—that is, automobiles require more lanes than heavy trucks.
5. FHWA State HCAS Model.

Each allocation method was used to determine total cost responsibility and assign equity ratios to each vehicle class examined in the study.

Vermont

Vermont has conducted four HCASs—in 1982, 1990, 1993, and 2005. The first was reportedly a comprehensive one. Then in 1989 and 1990 Vermont performed an extensive HCAS using an interlinked set of spreadsheets before the development of Excel's Visual Basic software that was developed and used in later HCASs. The 1990 Vermont study was unusual in that it was conducted by Vermont's Legislative Council, with substantial assistance from VTrans. In 1993, an in-house update of the 1990 study was performed.

In 2005, VTrans, using the expertise of an IT professional with substantial private sector experience, was the first known transportation department to complete an in-house HCAS using FHWA's State HCAS software after it was developed for Oregon and later generalized for all states. The 2005 HCAS was requested by the legislature to evaluate proposed changes to DMV fees. VTrans examined actual expenditures and revenue for the previous fiscal year. VTrans then ran different DMV revenue scenarios to calculate new equity ratios. Although the truck/auto equity ratios moved one percentage point closer to equity, that was by coincidence. Comparison with neighboring states was a more important consideration. VTrans' only outside assistance in this effort was a review by the manager of the consultant team that developed the model for FHWA, for a cost of less than $10,000 (Selle 2006).

STATE HIGHWAY COST ALLOCATION STUDY SELF-ASSESSMENTS AND ADDITIONAL GUIDANCE AND ASSISTANCE DESIRED BY STATES

Ten respondents prepared self-evaluations of the HCASs conducted in their state. In some cases, the state transportation officials were grading the performance of a contractor, whereas in others they were grading their own agency's ability to conduct the study, or some combination of the two. The self-evaluation covered the following elements:

- Technical issues relating to methods used and data collected;
- Accuracy of the methods;
- Credibility of the work among stakeholders;
- Coverage of vehicle classes;
- Coverage of all relevant funding sources, fees, and taxes; and
- Handling of special revenue factors.

The technical methods and data used in these studies were generally well reviewed, with seven of ten states rating these elements as good or excellent. The credibility of the work among the stakeholders was cited as a problem in some states, as was the limited coverage of vehicle classes. The ability of these HCASs to handle special revenue factors, such as public-private partnerships (PPPs) and tolls, was viewed as average or weak in four of the ten surveyed states (see Table 7). These issues were explored in greater detail earlier in this chapter and are studied in chapter five as well.

In terms of what would be most helpful to states considering conducting HCASs, a total of 72 individual responses were offered by 29 of the 33 states that returned a survey. Respondents were encouraged to select more than one response as appropriate. The 72 responses are broken down as follows: 18 states selected "copies of previous HCAS reports from other states," 14 selected "improved HCAS guidelines," 15 selected "software," 14 selected "conferences, networking, and/or federal workshops" and 11 selected "other." These results are presented in Table 8.

TABLE 8
WHAT STATES INDICATED WOULD MOST SUPPORT HCAS EFFORTS

Most Helpful	Responses
Copies of Previous State HCASs	18
Improved HCAS Guidelines	14
HCAS Software	15
Conferences, Networking, and/or Federal Workshops	14
Other	11
Total	72

As noted in Table 8, ten respondents selected "other." Other responses included the following

- The California respondent indicated that AASHTO should consider recommendations to guide states considering future HCAS and related studies.
- The Michigan respondent indicated that engineering knowledge about the effect of trucks with Michigan's weight limits would be useful.
- The Nevada respondent argued for legislative action consistent with the study results to motivate the state to conduct additional studies.
- The Ohio respondent noted that Ohio would just refer to national studies or studies from other states.
- The Wyoming respondent requested improved documentation from the FHWA for the FHWA State HCAS Model and also noted the need for more extensive vehicle class data for the entire highway system (detailed documentation for FHWA's 2001 State HCAS Model is available on the FHWA's website at http://www.fhwa.dot.gov/policy/otps/costallocation.htm.

TABLE 7
STATE SELF-EVALUATION OF HCASs

Elements	Excellent	Good	Average	Weak	Poor
Technical—Methods and Data	1	6	2		
Accuracy of the Methods	2	5	2		
Credibility of Work Among Stakeholders	2	4	1	2	
Coverage of Vehicle Classes	2	4	2	1	
Coverage of all Relevant Funding Sources, Fees, and Taxes	3	4	2		
Handling of Special Revenue Factors	1	4	3	1	
Total	11	27	12	4	0

CHAPTER FOUR

IMPACTS OF HIGHWAY COST ALLOCATION STUDIES

Generally, there has been a surge in the number of HCASs conducted at the state level immediately following the completion of a federal HCAS. As new HCAS methods and data are developed and tested at the federal level, they are used and in some cases enhanced at the state level. The research team identified the following state HCASs conducted since the 1997 Federal HCAS:

- Arizona (1999, 2000, 2001, 2002, 2005),
- Idaho (2002),
- Indiana (2000),
- Kentucky (1998, 2000),
- Montana (1999),
- Nevada (1999),
- Oregon (1999, 2001, 2003, 2005, 2007),
- Texas (2002),
- Vermont (2005), and
- Wyoming (1999).

Since the last federal HCAS was performed in 1997, ten states have performed HCASs but only three (Arizona, Kentucky, and Oregon) have performed more than one HCAS. Oregon has completed five HCASs since 1997 and today is required to complete an HCAS every two years. In 1999, the Oregon Senate passed Senate Joint Resolution (SJR) 44, an amendment to the Oregon Constitution requiring that revenues from fuel taxes and fees on motor vehicles be generated in a manner that ensures that classes of highway vehicles pay a fair and proportionate share of costs imposed on the highway system. Under SJR 44, the Oregon Legislative Assembly is required to provide for a biennial review and, if necessary, adjust highway-user tax and fee rates to ensure fairness and proportionality (Oregon Legislative Assembly 1999). SJR 44 referred the proposed amendment to the citizens of Oregon. The measure was approved by Oregon voters in the November 1999 special election.

The experience in Oregon, however, has become the exception rather than the rule. In recent years, the number of state HCASs being performed has been in decline, as illustrated in Figure 1, which charts the number of state HCASs being performed across time. Years in which federal HCASs were performed are highlighted with vertical lines. The trend line represents a four-period moving average. The figure clearly shows the surge in the number of HCASs performed in the years immediately following completion of a federal HCAS and demonstrates that there have been fewer of them conducted since the last federal study.

There could be a number of reasons for the decline in the number of HCASs being conducted, including an increased emphasis on revenue generation within states facing constrained budgets, an inability on the part of most state tax structures to fully implement study findings, and constrained research budgets that are used on other higher priority research. Some reasons for this recent trend are explored in the next section of this report.

Of the 33 states that completed surveys for this study, 26 indicated that the primary motivation for conducting an HCAS was to determine if its highway-user tax system was equitable, and 12 indicated that the desire to use the study findings to adjust taxes and fees to become more equitable was the principal reason for doing the study. Survey results suggest that the ability of most states to fully achieve cost responsibility by implementing HCAS findings has become increasingly difficult for at least two reasons: (1) the shift away from mileage-based forms of taxation, and (2) a political landscape that increasingly focuses on revenue generation from feasible sources rather than equity among highway-user classes.

The concept of cost responsibility is often broken down into two categories: horizontal and vertical equity. Horizontal equity refers to the fair treatment of user classes with the same vehicle class, whereas vertical equity refers to the fair treatment of different user classes with respect to each other. Horizontal and vertical equity are not fully achievable in most state transportation tax structures owing to the heavy reliance on registration fees, non-mileage-based weight fees, and motor fuel taxes.

Mileage-based taxes and fees can be used to more completely achieve equity and fully implement the findings of HCASs. In recent years, however, mileage-based systems, such as the weight-mile tax paid by heavy trucks, have been repealed in several states (Figure 2). Today, weight-distance taxes are imposed in only four states (Kentucky, New Mexico, New York, and Oregon), although many states once administered some form of weight-distance tax (Schultz 1994).

In the absence of a mileage-based tax system, HCAS study findings can still be implemented to achieve equity between broad vehicle classes through non-mileage-based weight fees

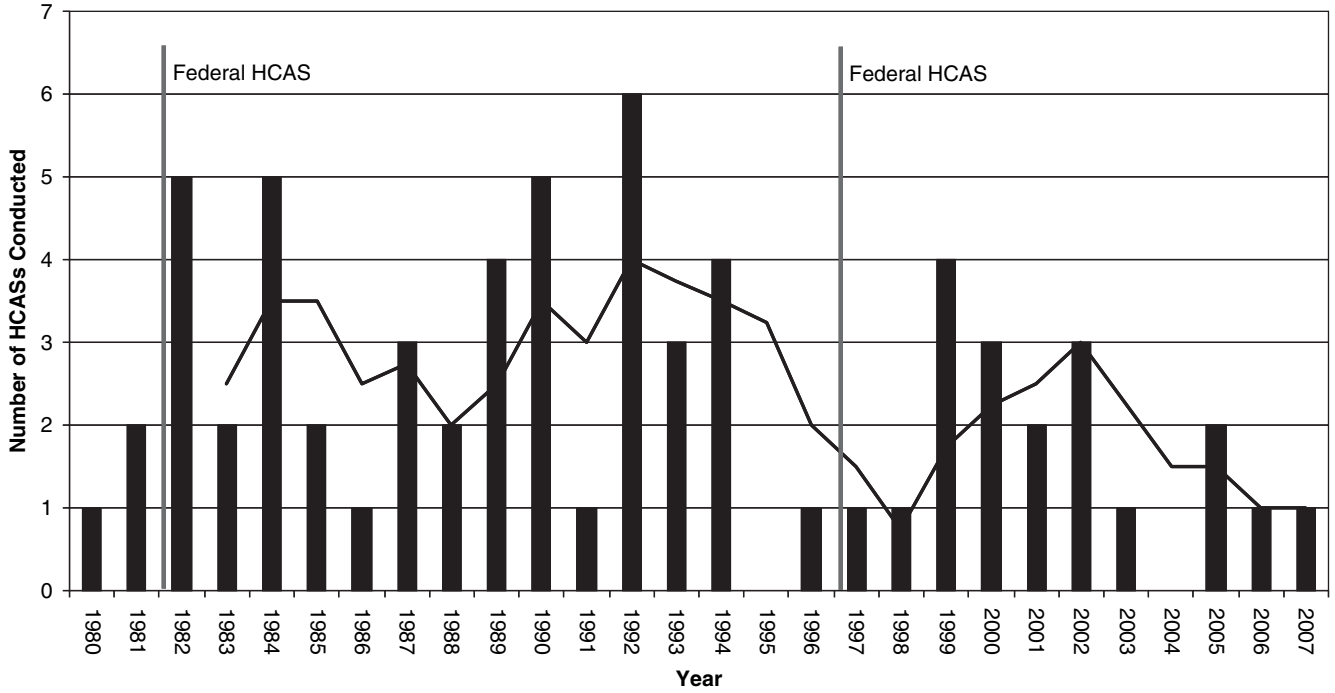

FIGURE 1 State HCAS frequency distribution (1980–2007).

or graduated registration fees, but cannot completely achieve equity within weight classes. HCASs can be used to evaluate the current tax structure and generate recommended adjustments to enhance equity generally among all highway-user classes.

Some states surveyed for this study indicated that it has become increasingly difficult to implement the findings of its HCAS owing to both internal and external political influences that have complicated the process and led to an uneven application of study findings. In Nevada, the findings of the state's HCAS have not been implemented since 1990, and the most recent HCAS performed in 1999 found that heavy-truck fees would need to be increased by $133.7 million to achieve an equitable balance between revenue and cost responsibility (*1999 Highway Cost Allocation Study* 1999). In Kentucky, studies were completed every two years between 1992 and 2000; however, disagreements over the extent to which evasion should be factored into the study and other considerations ended the practice.

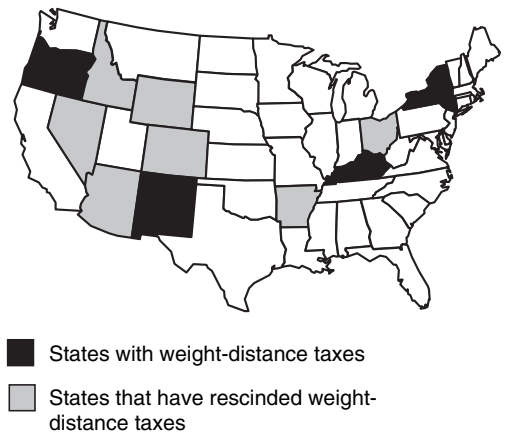

FIGURE 2 Weight-distance tax states.

In Oregon, the responsibility for conducting the HCAS was transferred from the Oregon DOT, the agency that pioneered the HCAS, to the Oregon Department of Administration Services. The Oregon Department of Administrative Services convened a study review team that included representation from the American Automobile Association, state agencies, academia, and trucking and shipping interests to refine the study's methodology and hired a contractor to conduct the study (Stowers et al. 1999). Although Oregon's detailed weight-mile tax schedule would enable a full implementation of the HCAS results, the Oregon Legislature since 1999 has moved all weight-mile tax rates in unison. Therefore, when the Oregon HCAS finds that heavy-truck tax payments are forecast to exceed cost responsibility by 5%, the Oregon Legislature responds by reducing all weight-mile tax rates by 5%. This practice has led to a disparity in terms of the cost responsibility among heavy-truck classes with the most recent Oregon HCAS projecting that tax payments from vehicles with declared weights of between 10,000 and 26,000 lb would exceed their cost responsibility by 26%, whereas tax payments from heavy trucks weighing between 80,000 and 105,500 lb would fall short of cost responsibility by 16% (ECONorthwest 2007).

One issue in planning HCASs that often affects the likelihood of implementation is the stated set of conditions for

studies. An example of such a condition often made is that an HCAS will exclude consideration of "highway needs." Another example of a condition that is sometimes made is that recommendations for any changes in tax structure will be balanced so that the results will be revenue neutral for the overall highway tax structure. This condition is often made in cases where one particular highway-user group is seriously concerned that a study may lead to a recommendation for a significant fee increase for vehicles in that class. Another possible outcome might be an agreement on a quid pro quo solution—for example, a tax or fee increase offset in value by a favorable change in a non-tax condition, such as liberalization on vehicle combination or length limits or restrictions on access to more parts of the highway network.

CHAPTER FIVE

GUIDELINES FOR ANALYSES NEEDED FOR HIGHWAY COST ALLOCATION STUDIES

The first six subsections of this chapter draw heavily on the guidelines that were prepared for the FHWA to assist states in properly applying the generalized State HCAS Model completed in 2002. It has been refined and updated as a product of this HCAS synthesis project.

EXPENDITURES

The work required to prepare expenditure data is usually one of the most time-consuming and tedious tasks involved in a state HCAS. Unfortunately, there is little or no standardization among the states in the available databases, and, therefore, examples of this work from previous studies provide only general guidance.

Tables 9 and 10 provide two examples of expenditure data developed by this project's study team for two different state HCASs. The "construction" or "capital expenditures" line items are usually taken directly from each state's STIP or the equivalent. Typically, a STIP will include officially adopted program expenditures for construction and related projects for several future periods—usually five years or longer. The STIP categories typically include several highway federal-aid categories plus a few other categories involving little or no federal aid—typically minor or specialized type projects such as resurfacing, restoration, rehabilitation, and reconstruction (4R) projects; sign and signalization improvements; rest area improvements; and toll facilities, buildings, and other capital improvements needed for the administration of highway and other state transportation programs.

In general, one can expect the composition of projects within each STIP program category to have approximately similar characteristics from a cost allocation perspective, but to have relatively different characteristics from projects in other program categories. For example, most 4R projects involve very high proportions of pavement rehabilitation, but very little new pavement construction, bridge work, or grading; most Interstate maintenance projects also involve high proportions of pavement rehabilitation, but they also tend to involve more work on various other highway elements than typical 4R projects. Most bridge projects on the other hand involve primarily bridge construction or repair, but very little pavement, grading, or other work.

Table 11 provides an illustration from a state HCAS of how construction program expenditures are broken down by cost allocation category. A conversion matrix such as this should be developed for each state from current project data to obtain an accurate and up-to-date basis for conversion of STIP expenditures into cost allocation categories. Once a conversion matrix of this type is developed for a state HCAS, it may be reused in subsequent studies in that state, with review and revisions as appropriate to reflect any changes in program categories or other factors that might change the matrix.

Data are usually available in each state to develop conversion matrices such as those shown in Table 11; however, they are contained in a wide variety of formats. Usually they are project-by-project records with quantities and/or cost estimates broken down into very detailed categories. Typically, the development of a matrix such as Table 11 will involve careful consideration of the definition of the individual quantities and the nature of the project, and often all of these factors are computer coded. For example, different categories of concrete may be used in pavements, bridge decks, and structures; different codes may be implemented for asphalt used for new pavements, resurfacing, and pothole patching, and different definitions of the purpose of the projects can be used to distinguish these elements when other differences in codes are inadequate.

A matrix should also be developed for each state to convert STIP expenditures into expenditures by highway class. These types of matrices are somewhat more likely to change over time, but are usually much easier to update from readily available project data.

Programmed expenditures should also be separated out by level of government for the source of funding for use in separate analysis by level of government, as will be discussed in a separate subsection. Other expenditures are usually projected each year for the STIP period by each state in a very general manner. This is done to provide a basis for estimating funds that will be available for highway construction and other capital expenditures after maintenance, other commitments, and administrative costs are subtracted from projected revenues.

Typically, these non-construction expenditure projections for the STIP period must be disaggregated from one or more broad categories into several categories required for cost allocation purposes. Often, the non-construction expenditure

TABLE 9
EXAMPLE OF EXPENDITURE CATEGORIES FOR STATE HIGHWAY COST ALLOCATION

Expenditure Categories	$ Millions
Transportation Department	
Construction and related	
construction (split into program and HCA categories)	146
project development (allocate as overhead)	4
other construction related	21
Maintenance and related	
highway maintenance	64
maintenance related (allocate as overhead)	4
Other operational functions	
ports of entry operations	4
other district operations	5
non-highway capital facilities (overhead or other)	4
highway safety	1
other highway operations (overhead)	7
Public transportation	
urban public transportation	2
intercity rail	0
Other modes of transportation	
aeronautics (not to be allocated)	1
ports, inland waterways, pipelines, etc. (not to be allocated)	1
Departmental services	
management services to be allocated (overhead on items to be allocated above)	8
management services not to be allocated (overhead on items not to be allocated)	0
support services to be allocated (overhead on items to be allocated)	5
support services not to be allocated (overhead on items not to be allocated)	0
MVA (often separate department)	
heavy vehicle fee apportionment programs (allocate to heavy-vehicle VMT)	1
audit portion of motor vehicles (allocate to heavy-truck VMT)	1
regulatory and administration related to motor vehicle dealers (allocate to all vehicles)	0
other MVA (allocate to all vehicles)	1
Subtotal, transportation department	280
Department of Law Enforcement	
Off-highway police services (not to be allocated)	11
Highway patrol (allocate to state highway VMT)	16
Alcohol beverage control (not to be allocated)	1
Academy and training programs (allocate pro rata share to VMT)	1
Heavy vehicle weight enforcement (allocate to heavy-vehicle VMT)	0
Heavy vehicle inspection programs	0
Other Departments (overhead on appropriate items above)	
Attorney general services to highway agencies	1
Courts hi ghway-related functions	1
Air quality and environmental programs related to highways	0
General administrative functions (pro rata for highways)	2
Highway-user revenue collection and related enforcement	0
Local Government Assistance for Street and Highway Programs	
To cities (to be split as appropriate)	22
To counties and highway districts (to be split as appropriate)	51
Total	386

TABLE 10
PROGRAMMED HIGHWAY-RELATED EXPENDITURES (STATE AND FEDERAL SOURCES)

Sources	State ($ Millions)	Federal ($ Millions)
State Highway Account (excluding state aid)		
Maintenance of state highway system	465	0
Highway operations (other non-capital)	314	0
Capital expenditures (includes project support)		
4R projects	150	333
minor projects	58	0
bridge projects	91	40
transportation system management projects	34	40
major highway projects	198	173
transit and rail	203	178
Transportation Planning and Intercity Rail	42	30
Other Expenditures Related to the State Highway System		
Department of motor vehicles	351	0
Highway patrol (enforcement, safety, inspections)	548	0
Other agencies' highway-related expenditures (courts, emissions control, user-revenue collection, etc.)	70	0
State Aid to Local Governments		
Capital expenditures	378	0
Maintenance	310	0
Transportation planning, bicycle lanes, emergency repairs	88	0
All other	107	0
Federal aid to local governments	0	367
Total	3,407	1,161

TABLE 11
ILLUSTRATION OF THE CONVERSION OF A STATE'S FIVE-YEAR CONSTRUCTION PROGRAM EXPENDITURES INTO HIGHWAY COST ALLOCATION CATEGORIES

	Percentage Split by Cost Allocation Category for Each Program Category							
Source	New Pavement	Rehab. Pavement	New Bridge	Replace-ment Bridge	Bridge Repair	Grading	Other	Total
Interstate Maintenance	2%	54%	0%	11%	1%	3%	29%	100%
National Highway System	11%	31%	1%	4%	1%	26%	26%	100%
Surface Transportation Program (STP)—State	9%	36%	0%	11%	1%	26%	17%	100%
STP—Local Rural	11%	35%	0%	13%	0%	35%	6%	100%
STP—Local Urban	2%	17%	0%	6%	6%	14%	55%	100%
STP—Safety	0%	14%	0%	0%	0%	5%	81%	100%
STP—Enhancement	9%	36%	0%	11%	1%	26%	17%	100%
Congestion Mitigation and Air Quality	9%	36%	0%	11%	1%	26%	17%	100%
Bridge Projects	6%	3%	0%	69%	1%	9%	12%	100%
Demonstration Projects	7%	66%	7%	0%	0%	12%	8%	100%
4R Projects	5%	67%	0%	1%	6%	6%	15%	100%

projections will be broken down into agency programs or formula allocations—for example, MVA, state police, and state aid to local governments. If not, the first task is usually to estimate such broad breakdowns based on trends and interviews with program administrators.

A critical next step is usually to break down administrative expenditure projections into broad cost allocation categories (e.g., construction, maintenance, motor vehicle, police, transit, and other modes). The critical question to be raised in this context is how such administrative costs should be allocated to vehicle classes. In some HCASs, most or all administrative costs have been allocated as common costs, often using VMT as the allocator. However, most practitioners prefer the more refined approach that has been used in many recent HCASs—that is, treating each major component of administrative cost as an overhead on the specific program category. For example, construction engineering and construction management costs are allocated to vehicle classes in proportion to the results of the cost allocation for direct construction expenditures. Similarly, administrative and management costs for highway construction and maintenance as a whole are allocated based on the combined cost allocation results for direct construction and maintenance expenditures.

Motor vehicle administrative costs are usually treated somewhat differently. They are first broken down into functions relating to different classes of vehicles that are administered in a different manner—usually two or more classes: (1) heavy and larger vehicles whose registration fees are prorated among the states, and (2) all other vehicles, sometimes further divided into light- and heavy-vehicle classes if administrative costs per vehicle are significantly different between these two classes. Police costs are also usually broken down into vehicle classes covered by the various functions (e.g., vehicle inspection, weight enforcement, and general traffic service and enforcement).

The final major step in analyzing expenditure data is to link all expenditure projections to cost allocation factors. In many cases, this requires significant further analysis to provide a basis for splitting expenditures into cost components, such as the breakdown of pavement expenditures into broad classes of pavement work, the cost of pavements of minimum thickness versus the cost of added thickness necessary for supporting axle-load repetitions, and the expenditures for different types of maintenance activities.

VEHICLE-MILES OF TRAVEL AND RELATED DATA

The travel and related data requirements for the FHWA State HCAS Model include annual statewide VMT broken down into the following categories:

- Vehicle configuration,
- Registered gross weight,
- Fuel type, and
- Functional class of highway or other user-specified highway classes.

The primary source for the basic set of VMT data in most states is the data compiled for the Highway Performance Monitoring System, which is reported each year by each state to the FHWA. These data include VMT by 12 vehicle configurations (13 if motorcycles are separated out) and 12 highway functional classes.

Some states may not have all the breakdowns required, such as splits of VMT for single-unit trucks broken down into two, three, or four or more axles, or splits of combinations into all of the standard seven classes of combinations. In such cases, a state's VMT for larger classes can be disaggregated into the more detailed classes using FHWA data. FHWA may have developed estimates for more detailed breakdowns for that state and can supply data from other neighboring states or states with similar economies and other characteristics.

The developers of the FHWA State HCAS Model recommended that each state analyze trends in VMT by vehicle configuration and functional highway class for the most recent several years. Unless a state routinely performs such analysis in the process of preparing each year's estimates, there are usually irregular trend lines for some of the breakdowns, particularly for the breakdowns that have very small shares of total VMT (e.g., three- and four-axle combinations, and six- or seven-axle doubles).

The analysis of trends in the breakdowns of VMT will usually result in the need for a few small adjustments in the percentage splits for one or more of the several years of data. Once this is done, a decision should be made as to how to project these percentage splits, either by (1) using the most recent splits for the future year(s), (2) using average splits for the several years, or (3) projecting trends in changes in the splits. Care should be taken in choosing the third option, however, because such trends may reflect short-term fluctuations that are not likely to be sustained for long. Thus, a compromise might be made between the first or second option and the third option.

Annual mileage per vehicle and gallons per mile are variables for which good estimates have been developed for each state in the default data contained in FHWA's 2001 State HCAS Model, based on analysis of the 1992 Truck Inventory and Use Survey (TIUS). Some refinements in these estimates might be made, however, if a state desires, using more detailed analysis of that state's 1997 and 2002 VIUS data.

Estimates of new power unit prices were provided in the FHWA State HCAS Model's default database in the form of equations expressing price as a function of registered gross

weight for heavy trucks, and as a single average value for all light vehicles. These values and relationships are approximate estimates judged to be satisfactory for attributing ad valorem revenues (e.g., sales taxes, title fees, vehicle license fees, and other fees that vary as functions of new vehicle price or depreciated value). However, if a state has a major portion of its highway-user revenue from ad valorem taxes, it may wish to refine these values and relationships by analysis of recent new vehicle prices, using manufacturers' data or other published sources.

The default data in the FHWA State HCAS Model used for splitting VMT for 12 vehicle configurations into VMT for 20 configurations are based on national VMT data developed in the 1997 Federal HCAS. These factors are sound estimates at the national level, but are considered to be only very approximate estimates at the state level. They may be highly inaccurate for some states that have unusual size and weight limits (e.g., Michigan) or concentrations of industries that use particular types of configurations (e.g., particular types of natural resource hauling in some Rocky Mountain states). Such states may wish to perform special analysis of VMT for heavy- and longer-vehicle configurations, using either detailed Highway Performance Monitoring System data and/or WIM data. Both types of data can be used for such analysis.

Registered gross weight breakdowns for each vehicle configuration are likely to vary substantially among the states. The data provided with the 2001 State HCAS Model are only representative data—that is, not considered to be accurate enough for drawing conclusions regarding the equity of the tax structure for different registered gross weight (RGW) classes. Unfortunately, there is no common source among the states for this variable. VIUS might be used for doing this; however, we are not aware of any analysis of this type that has been done for any state. Generally, any state that has an interest in developing estimates of cost responsibility of vehicles by RGW has specialized data that can be used. The best source of this type of data exists in those few states that have tax records on reported mileage by RGW—typically those states that have weight-distance taxes. Many states also maintain good databases on registered vehicles by RGW; however, these data are not adequate, by themselves, for estimating breakdowns of VMT by RGW because of (1) the wide variation in annual miles of travel as a function of RGW, and (2) the wide variation in out-of-state travel as a function of RGW. VIUS data can be analyzed to develop estimates of both of these relationships, and to use the resulting relationships in conjunction with registration data, to develop estimates of VMT by RGW.

Estimates of fuel type splits by vehicle configuration that are in the State HCAS Model are considered to be sufficiently accurate to be used in all state HCASs. They are based on an excellent database from one state, and slight inaccuracies in this variable have no significant effect on the results. This is true because the vast majority of all light vehicles are gasoline-powered and the vast majority of all heavy vehicles are diesel-powered, particularly when vehicles are weighted by annual miles of travel.

Average power unit and trailer life have a very small effect, or no effect at all, on the results of the revenue attribution process. They effect only the results of revenue attribution for ad valorem taxes, and then only to a small extent. Therefore, most states need not perform any analysis of this variable unless ad valorem taxes are a very large share of total tax revenue.

PAVEMENTS AND RELATED DATA

A good HCAS model, such as FHWA's 2001 State HCAS Model, should be designed to handle four pavement cost categories: new flexible pavements, new rigid pavements, flexible pavement repair and reconstruction, and rigid pavement repair and reconstruction. Each should be broken down into the standard 12 functional classes of highway (or other types of highway classes) and by any special funding categories the user wishes to analyze. FHWA's State HCAS Model contains representative values of expenditures for each highway cost allocation category, including the previously mentioned four pavement categories.

The following additional inputs may be required for pavement cost allocation, all of which have default values provided in FHWA's State HCAS Model:

- Distribution of VMT by vehicle configuration and highway class.
- Operating gross weight distributions by vehicle configuration (and optionally by highway class).
- Axle-weight and axle-type frequency distributions for each operating weight and vehicle class.
- Typical pavement sections and traffic proportions that represent the flexible and rigid pavements for each highway class.
- Number of miles on each highway class (to determine average daily traffic loadings from VMT data) for new pavement cost allocation.
- Annual ESAL growth rates by highway class for new pavement cost allocation.
- Pavement design parameters applicable to the state in question for new pavement cost allocation.
- Minimum pavement thicknesses for rigid and flexible pavements.
- Pavement distress distributions and load-equivalency factor regression coefficients for each highway class, for pavement rehabilitation cost allocation.
- A conversion key, if necessary, to convert state-specified highway classes to the 12 highway functional classes used in NAPCOM.

The default values supplied with the State HCAS Model are all based on the 1997 Federal HCAS. These data include:

- VMT data by vehicle configuration and functional highway class;
- Minimum pavement thicknesses and the specification of which state and coefficient option to use;
- Operating gross weight distributions by vehicle configuration, and space for the user to specify different weight distributions for selected highway classes or groups of highway classes;
- Axle weight distributions for each vehicle configuration and operating gross weight group; and
- All other pavement data required by the State HCAS Model.

The guidelines that accompany the model also contain advice for modifying the data for use in each state.

BRIDGE DATA

A sound HCAS model should be designed to handle four bridge cost categories: new bridges, bridge replacement, bridge repair, and possibly special bridge costs. An example of special bridge costs is the retrofitting of existing bridges for earthquakes.

The following additional inputs are typically required for bridge cost allocation, all of which have default values provided with the State HCAS Model:

- Assignment of vehicles to bridge increments based on their live-load moments,
- An allocation of the cost of various types of new bridges to bridge increments,
- Information on the types of material and span lengths for new and replacement bridges,
- Inventory ratings of bridges that are to be replaced,
- An estimate of the percentage of bridge replacement costs owing to structural deficiencies in existing bridges,
- An estimate of the percentage of bridge repair costs that are load-related, and
- An estimate of the percentage of special bridge costs that are load-related.

Default values based on the 1997 Federal HCAS are provided for the rest of the information required for the State HCAS Model. The guidelines provided with the State HCAS Model also provide detailed advice for handling each of the following operations:

- Assignment of vehicles to bridge increments,
- Allocation of new bridge costs to bridge increments,
- Types of material and span lengths for new and replacement bridges,
- Inventory ratings of replaced bridges,
- Bridge replacements resulting from structural deficiencies, and
- Load-related bridge repair and special bridge costs.

MAINTENANCE AND OTHER DATA

In addition to the travel and vehicle characteristic data and inputs required for pavement, bridge, and other costs in a sound HCAS model, a carefully performed maintenance cost allocation procedure should require:

- Expenditures for different categories of maintenance work, broken down by highway class: travel-related maintenance, wear-related flexible pavement maintenance, wear-related rigid pavement maintenance, axle-related maintenance, truck-mile-related maintenance, light-vehicle-related maintenance, and possibly rest area maintenance; and
- Specification of allocators for each of these cost categories.

Many states maintain detailed records of maintenance costs by specific type of maintenance activity, such as pavement surface patching, joint and crack filling, culvert cleaning, bridge painting, snow plowing, etc. These records also often include breakdowns of maintenance costs for specific routes or sections of routes (e.g., by county or highway district).

When such data are available, the user's primary task is to decide what allocation factors to use for each maintenance activity or group of activities. An analyst doing a state HCAS may want to consult the example contained in an appendix to the guidelines for application of FHWA's State HCAS Model as a guide in preparing a similar table with that state's maintenance activities (Sydec 2000).

In the event that a state does not maintain detailed records of maintenance cost broken down by specific activity, the user of the model should make estimates of breakdowns of maintenance expenditures by major class of activity through interviews with the maintenance managers who are responsible for assigning work to crews. This may require meeting with managers in each district to fill out forms that break down known totals and/or subtotals of maintenance expenditures into the desired shares by major class of activity.

A few states keep maintenance costs by functional class of highway (or other highway classes that might be used in HCASs). However, more commonly there is a significant problem in converting costs to these highway classes. A fairly common problem is the need to convert costs by route or segment of the route into costs by highway class. This typically involves building a conversion matrix, using the assumption that maintenance costs per lane-mile are constant, at least for each highway class. Average maintenance costs per lane-mile for each highway class can be estimated from routes that

are entirely in each highway class. Maintenance costs for routes that are in more than one highway class can then be split between highway classes based on lane-miles in each highway class and average maintenance costs per lane-mile for the different highway classes.

The guidelines that accompany FHWA's State HCAS Model also include specific advice and options for the allocation of the following other categories of highway costs:

- Grading costs,
- Residual allocators,
- Width shares,
- General construction costs and transit costs,
- Multi-highway system costs,
- Other travel-related costs,
- State police traffic management, and
- Vehicle registration costs.

ISSUES IN REVENUE ATTRIBUTION

The revenue attribution process is a straightforward splitting of revenue actually collected or projected to be collected for a future program period among the vehicle classes, separately for each highway-user tax or fee. Usually this is done in a two or more step process; for example, by splitting fuel taxes into revenue by fuel type, then into light versus heavy vehicles, and finally into the specific vehicle classes using historical or projected fuel economy by vehicle class based on data reported in the VIUS conducted every five years by the U.S. Census Bureau.

A key part of accurately attributing revenue is to split vehicles in each class into full-fee paying vehicles and exempt-, partially-exempt, and special-fee paying vehicles, if any, based on vehicle registration data. Many states have all three non-full-fee-paying vehicle categories, and the number falling into each class varies by type of tax or fee.

In properly assessing the equity of a state's overall highway-user tax structure, only the full-fee-paying vehicles are generally included. It is important to recognize that the proportion of vehicles that are full-fee-paying varies widely by vehicle class. In most, if not all states, these vehicles are a small minority of buses, but a majority for all other vehicle classes. For these other vehicle classes, subsidized vehicles (mostly government owned) usually make up a larger portion of all vehicles for some of the lighter single-unit truck categories. However, some subsidized vehicles are usually found in all vehicle classes.

Two analyses that are critical in the revenue attribution process are:

1. The development of carefully fitted curves for fuel economy by fuel type as functions of registered weights of vehicles. Experience shows that this should be done separately for single-unit trucks and combinations (which generally are more fuel efficient than single-unit trucks at most registered weights). Consideration should be given to developing curves separately for two categories of fuels: gasoline-powered vehicles and all others; that is, those powered by diesel and other special fuels.
2. The development of another carefully fitted curve for average annual mileage per vehicle as a function of registered weights of vehicles. Experience shows that this should also be done separately for single-unit trucks and combinations, which generally travel more annual miles than single-unit trucks, particularly at most higher registered weights.

Curves can be developed from VIUS data and have been done using the 1992 TIUS in the default database that is part of the FHWA State HCAS Model. Default data for much of the other data needed for revenue attribution can also be found there, along with guidelines on how these data can be used in the model. Experience in preparing these default data suggests that it is important to focus primary attention on data in the VIUS for each state rather than relying on national data. However, care is needed in doing this because individual state-level data are based on much smaller samples and tend to create much more erratic plots. The curve fitting often requires careful use of judgment and often requires supplementary review and analysis of data for states that are similar in their economies and geography.

To perform a sound revenue attribution process it is unnecessary to deal with some related issues that have arisen in some states. For example, a tangential diversion from the basic analysis required for good practice in revenue attribution or cost allocation is to confuse subsidies with costs and then allocate the amounts of a tax subsidy to the vehicle classes or any other taxpayer. Economists often consider subsidies as costs in the sense one might think of the loss of revenue as an "opportunity cost" to the economy. However, a tax subsidy is by no means a cost attributable to vehicle classes in an HCAS because the responsibility for extending the subsidy is that of a policy maker or legislator and not the highway user.

Another issue dealt with in at least two recent state HCASs revolves around the issue of evasion. This is somewhat related to the analysis required in the revenue attribution process in that an analysis of miles of travel within a state by full-fee-paying vehicles could in theory be used to make rough estimates of evasion of diesel fuel taxes or weight-distance taxes. In turn, some states calculate revenue that is not being collected and then effectively consider that lost tax revenue when determining the fair share that each vehicle class should pay. For example, if payments from heavy vehicles fall 10% short of cost responsibility but evasion is estimated at 10%, the argument has been advanced that no adjustments to tax rates are necessary. Rather, those who are paying are currently meeting their cost responsibility

and the state should increase revenues from heavy vehicles by addressing the evasion issue. This argument is generally not accepted by HCAS practitioners and evasion analysis is not a generally accepted part of a sound revenue attribution process. Evasion studies are often extremely complex and well beyond the scope of a typical HCAS. When constructing an evasion estimate, the simple analysis of VMT and MPG is not an accepted method owing to the margin of error in VMT and MPG calculations. The margin of error in these calculations typically exceeds the expected level of evasion.

DIFFERENT LEVELS OF GOVERNMENT AND EQUITY RATIOS

Unfortunately, many state HCASs have not recognized the importance that the level of government has in influencing study findings. Many states' equity ratios depend on what levels of government are being considered. For example, in the case of the 2002 Idaho HCAS, when state and federal programs were combined, the typical 18-wheelers (combination trucks with registered weights in the 70,000-lb to 80,000-lb range) were found to be substantially underpaying with an unadjusted equity ratio of 0.74 and adjusted equity ratio of 0.89 (percent of total state and federal revenue paid divided by percent of total cost responsibility for state and federal programs combined). However, when only state programs were considered, these typical 18-wheelers were substantially overpaying (ratios of 1.23 and 1.27 for the unadjusted and adjusted equity ratios, respectively).

Historically, state HCASs more often focused on the state highway network, state taxes and fees, and state expenditures for highways. However, once the Interstate network was completed and the use of federal and state funds became more flexible, more studies have examined at least state and federal funds (Virginia and Wisconsin), whereas others have examined federal, state, and local funds as well (Arizona, California, Idaho, Indiana, Nevada, and Oregon).

Programmed expenditures are generally separated out by level of government for the source of funding, as the example provided in Table 10 illustrates. A sound highway cost allocation model should provide for separate allocation of expenditures for (1) state funds used in state-level programs; (2) state aid to local governments; (3) federal aid and possibly, depending on the level of state interest, policies, and the size of the program, direct federal construction and operations on federal lands; and (4) local expenditures from local funding sources, again depending on the level of state interest and policies. Separate allocation of expenditures for each level of government makes it possible to present results in different ways (e.g., state and federal separately or in combination).

Revenues from each level of government should be analyzed separately for essentially the same reason. In general, revenues and expenditures for any selected period for the analysis cannot be expected to be exactly equal, either as a whole or for any level of government. Even in states where, either by established legislative policy or by constitutional requirement, all revenues are dedicated for highway purposes, there will be differences, if only resulting from lags between revenue collection and obligations of funds or actual expenditures.

In some states, and at other levels of government, users pay taxes or fees that are legally not considered highway revenues. In other cases, highway revenues are used for other modes based on the argument that those expenditures benefit highway users by reducing congestion and/or reducing the need for costly highway improvements. More often, highway programs are paid for in part by non-user revenues (generally without regard to any local connection, such as when general revenues are used) or, alternatively, user revenues are diverted for other purposes, such as deficit reduction or balancing budgets.

In any case, good practice requires proper accounting for all user fees on the revenue side, regardless of where they are used, and all highway-related expenditures, regardless of the source of funds (at that level of government). HCAS practice generally includes the reporting of these imbalances, and then to fairly assess the tax structure's degree of equity for each vehicle class, examiners generally modify raw equity ratios to "adjusted" equity ratios by expressing each ratio as the percent of total user revenue paid divided by the percent of total cost responsibility.

The level of interest and responsibility that states have for local street and highway programs varies widely. However, most states will at least include an analysis of cost responsibility for state aid to local governments for highway construction or for highway construction, maintenance, and other highway-related programs.

Some states have also done separate analysis of cost responsibilities for local highway expenditures by local governments from their own local funds. For almost all states, these expenditures by local governments are primarily from local non-highway-user revenue sources—for example, general revenues or property taxes. Many states, however, do have some local highway-user taxes or fees, such as vehicle registration fees or fuel taxes. However, these local sources usually yield a relatively small amount of revenue compared with total local highway-related expenditures from local funding sources.

If a state wishes to perform an analysis of cost responsibility for local expenditures from local sources, practitioners generally recommend that a parallel analysis of local highway-user revenues also be conducted, to the extent that such local highway-user taxes exist, to present a complete picture and produce local level equity ratios. Typically, these equity ratios will be small; for example, in the range of up to only about 0.2 or less.

A survey of local governments to determine how funds are used is a principal additional task that is necessary in most, if not all, states to do an equity analysis at the local level. Survey forms may be sent either to a sample of local governments (appropriate in states with many local governments of the same type) or to all units of local government (appropriate in states with relatively few units of each type of local government). If samples are used, a representative sample should be implemented for each type of local government that has responsibility for streets and highways (e.g., cities, towns, counties, and local highway districts).

One possible way of simplifying the local-level analysis is to reduce the number of highway-functional classes to just one for local rural areas and one for local urban areas. This eliminates the need to develop data needed to split local expenditures among several highway-functional classes; however, this raises the additional complication of preparing data specifically for the user-defined highway classes or preparing special tables to convert default data prepared for the 12 functional classes to data by the user-defined highway classes.

The federal-level analysis is very similar to the direct state-level analysis. When compared with the local-level analysis, it is simpler in one important way—no special survey of expenditures is necessary. The major complexity involved in the federal analysis is that state and federal expenditures should be separated from each other at the most detailed level in preparing inputs. Ideally, this should be done in analyzing project-level data to prepare factors for converting programmed expenditures into expenditures by cost allocation category. For example, a state will normally have both state and federal funds programmed separately for several construction categories (e.g., interstate maintenance, National Highway System projects, and 4R projects) and will have to analyze a project database to develop two matrices (for state and federal funds) to convert these programmed expenditures into cost allocation categories (e.g., new pavements, pavement rehabilitation, and new bridges). Similarly, separate sets of factors should be developed for splitting state and federal expenditures into classes of highways.

States with substantial direct federal construction programs may choose to include these expenditures in the federal-level analysis. *Highway Statistics* has data on such expenditures by state for historical years and these can be used with appropriate growth factors for a forecast year. Most of these expenditures occur on lower-level rural functional classes of highway (see http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm). Relationships developed for state-level construction programs that are concentrated on these types of highways (e.g., secondary highway programs) can be used for most direct federal construction programs.

The federal revenue attribution process should develop revenue control totals by type of federal tax using data from *Highway Statistics* for historical years with appropriate growth factors for a forecast year.

EMERGING ISSUES AND OTHER PROGRAMS

Equity principles should logically be applied to any highway program involving collection of substantial user fees and/or expenditure of substantial funds for highway-related purposes. A prime example of a common program of substantial size is bond financing of highways with repayment from user fees. In the simplest case, there is a potentially large equity imbalance in that current highway users are the primary beneficiaries and future highway users are the source of the primary payments. Cases like this can be evaluated in equity terms using all the relevant good practices described in these guidelines.

Toll systems are another potentially important application of equity principles. FHWA's State HCAS Model was set up specifically to conduct such an analysis because the FHWA understood the potential for growing extensions of toll systems. Automatic toll collection systems and associated regional fund transfer systems are now in place, and there is growing evidence that users are accepting such systems, in part because the user payments are more convenient.

The important thing to note when it comes to toll systems, particularly as they are considered for widespread highway system extensions, is that they provide the potential for real-time payment to be made based on short-run marginal costs. Of primary interest from an equity perspective is that the basic supporting argument for implementing real-time variable pricing is that the external or social costs of congestion could cease to exist (to the extent that the costs are accurately estimated and applied) and could, instead, become "internal" highway-user costs.

High-occupancy toll (HOT) lanes also represent an emerging issue with an important equity dimension. HOT lanes are expanding in heavily congested regions around the country. These are the only significant operational systems for which external congestion costs have largely, if imperfectly, been internalized. The algorithms being used in HOT lane systems are designed to apply real-time adjustments to the tolls collected so that specified levels of service will be maintained.

For toll systems and HOT lanes, the equity analysis issues that arise are: (1) what are these short-run marginal cost-based fees, and (2) how do they compare with the actual payments being collected based on the algorithms being used?

Finally, the other increasingly large emerging category involving large equity questions are PPPs. As with bond programs, a typical PPP involves up-front private capital subsidizing current and near-term future users, and subsidies of those users by future users on a long-term basis.

WEIGHT FEES AND OTHER SPECIAL FEES

Unfortunately, many states charge weight fees and other special fees with little or no attention to cost responsibility of the vehicles involved. Often these fees are based only on the administrative cost of issuing permits or registering vehicles in special classes.

As a result of this issue, a *Special Vehicle Analysis Workbook* was developed and refined in studies conducted for several states (California, Idaho, Oregon, and Vermont), and was incorporated in FHWA's State HCAS Model. The workbook provides estimates of cost responsibility and revenue generated for a user-specified vehicle based on the results of the state's HCAS. The workbook can be used to answer many types of "what if" questions for any selected vehicle. A typical question might be: "What permit fees should be charged for a particular truck configuration operating at *x* miles and *y* weight in order for it to fully cover its cost responsibility?" Another example might be: "How much should the registration fee (or any other fee) be increased (or decreased) in order to have a truck at *x* registered gross weight cover at least 95% of its cost responsibility?"

In the workbook, the user can select any type of vehicle from a list and modify any of the characteristics associated with the selected vehicle as desired. Unless the user specifies different values, the special vehicle characteristics are determined using default values based on the characteristics of typical vehicles operating in the state. The user can override any or all of these default values. At a minimum, the user must specify the levels of government for the analysis, the vehicle configuration, RGW, and fuel type. The workbook will then provide default values for all other vehicle characteristics.

REGIONAL ISSUES AND POSSIBLE REGIONAL APPROACHES TO HIGHWAY COST ALLOCATION STUDIES

Experience has shown that state legislators, particularly in geographically smaller eastern states, give major attention to the tax rates and fees in surrounding states. This is especially true for taxes and fees applied to heavier trucks, because of pressure to standardize taxes and fees on a regional basis. Very large proportions of heavy trucks operate on an interstate basis and can easily change their base state to states with lower flat fees (as distinct from fees based on mileage operated in each state).

This suggests that some type of regional approach to the evaluation of tax structures might be useful. Examples of similar efforts in the past in related highway issues include the periodic regional conferences organized by AASHTO and its regional affiliates and the series of regional conferences and studies organized by states with the financial support of FHWA to establish mechanisms for regional cooperation in the administration of services to heavy interstate truck operators. This latter category included efforts to develop "one-stop shopping" services at specific locations or through on-line service, both for individual states as well as on a multi-state regional basis.

Regional cooperation in this field could lead to the actual conduct of regional HCASs in which most or all of the analyses described in the guidelines would be done on a regional basis, including evaluation of options for improvement of the equity of highway taxes and fees.

DEVELOPMENT AND USE OF SIMPLIFIED HIGHWAY COST ALLOCATION STUDY PROCEDURES

Unfortunately, relatively little has been done to develop and refine simplified approaches to HCASs with the exception of the work performed by Arizona as described in chapter three and summarized in Table 6. The comparison of equity ratios in that table shows that the simplified model produced equity ratios that were in close agreement with the comprehensive HCAS for autos and buses, and although not shown in that table, were also close for the entire heavy-truck class. However, because the results produced a much higher equity ratio for single-unit trucks (1.41 versus 0.90) and substantially lower ratio for combination trucks (0.81 versus 0.93) suggests that the simplified model might be improved by using different sets of allocation factors for these two broad classes of trucks. The overall approach would appear to lend itself to easy refinements along these lines.

The *Special Vehicle Analysis Workbook* contained in the FHWA State HCAS Model described previously employs a different approach that also could be applied relatively easily to each vehicle class (as distinct from its application to special vehicles applying for permits or other special fee classes), and has the advantage of producing more accurate equity ratios because that model utilizes all of the important results of a recent comprehensive HCAS in its internal calculations of both cost responsibility and revenue payments.

The other experience of note is the sensitivity analysis performed recently by Vermont in completing and refining its 2006 HCAS using the FHWA State HCAS Model. VTrans used the model to explore how sensitive the equity results were to a variety of input factors. VTrans suggests that this approach might be used in a more rigorously organized manner to develop a simplified model.

ALLOCATION OF EXTERNAL COSTS

The term "internal costs" includes all costs of highway-related programs and use of highways that result in public expenditures. This is to distinguish such costs from "external" or "social costs." External costs considered in the HCAS literature (e.g., congestion, crash costs, air and noise pollution) are

somewhat mistakenly thought of as costs that are entirely external to user payments and, therefore, are borne by non-highway users (the larger society). In reality, the costs that are usually thought of as external or social are mixed—partially external and partially internal. For example, congestion results in wasted fuel, which increases highway-user costs. Air pollution is an example of an external cost that is borne by society rather than the highway user, although in some highly polluted areas such as most of Southern California air pollution control costs are significant public expenditures. These costs should be included in every HCAS to the extent that they can be identified in state, regional, and local agency budgets.

The costs associated with congestion in large urban areas have grown significantly in recent years. In 2003, congestion resulted in 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel at a cost of more than $63 billion (Schrank and Lomax 2005). Most but not all congestion costs are borne by urban highway users through fuel costs, wasted time, and vehicle maintenance costs.

Highway users also impose the costs associated with vehicle crashes on society. How significant are these crash costs? The *Economic Cost of Motor Vehicle Crashes* report constitutes one of the major sources of crash cost information in the United States. The report estimated the economic cost of all motor vehicle crashes in the United States in 2000 at $230.6 billion (Blincoe et al. 2002). This study monetized the costs associated with 41,821 fatalities, 5.3 million non-fatal injuries, and 28 million damaged vehicles. The study also included a number of cost elements:

- Productivity losses,
- Property damage,
- Medical costs,
- Rehabilitation costs,
- Travel delay,
- Legal and court costs,
- Emergency services,
- Insurance administration costs, and
- Costs to employers.

The costs included those associated with both police-reported and unreported crashes. The crash costs are stratified by severity according to the Abbreviated Injury Scale. This study examined crash costs associated with all vehicles, including both automobiles and heavy trucks. The average crash cost when all vehicles are included is $14,102 (2002 dollars) per crash.

Although significant, crash costs are partly internal because some of them are paid for by users or public agencies (e.g., insurance costs, police and highway patrol expenditures, and state and local government emergency response organizations). However, the external costs are usually much larger than these internal costs. The largest of these in magnitude is the cost of loss of life, loss of productive life owing to injuries, and property costs not covered by insurance. The internal or external costs are often omitted entirely from HCASs, except for some studies where the small portion that shows up in highway patrol or other state agency budgets is included.

Pollution costs vary widely depending on local environmental and congestion conditions. In most areas, only a relatively small proportion of total external costs are pollution costs; however, they are a relatively high proportion in the Los Angeles basin and in several of the largest urban areas. Most pollution costs are true social costs. Extra fuel costs cover only a very small portion of these costs.

Noise costs are localized and are largely internal rather than external costs. Some highway noise does negatively affect local communities, although its impact has been greatly reduced by noise walls and is nearly entirely internalized now for most new construction.

Allocating the external costs associated with congestion, air pollution, noise, and vehicle crashes would add to the breadth and completeness of HCASs, but these costs have not been historically included in federal and state studies. Arguments offered against the allocation of these social or external costs have included that they are much more difficult to quantify than direct costs and that states do not have in place a set of user charges to cover these costs (Stowers et al. 1998).

In an addendum to the 1997 Federal HCAS, the U.S.DOT estimated the costs associated with air pollution, crash costs, congestion, and noise (Table 12). The economic costs associated with air pollution are tied to the mortality, chronic bronchitis, and other heart and respiratory diseases resulting from the inhalation of particulate matter, ozone, nitrogen dioxide, carbon monoxide, and ozone in vehicle emissions. Air pollution costs were estimated based on EPA models used to estimate the economic benefits of the Clean Air Act and on other studies of the air pollution costs tied to vehicle emissions (McCubbin and Delucchi 1998). When applying this methodology to vehicle emissions, the authors performed sensitivity analysis with respect to the costs associated with premature death. As shown, when including the time, fuel, and maintenance costs associated with congestion

TABLE 12
ESTIMATES FOR SOCIAL COSTS OF MOTOR VEHICLE USE ($ MILLIONS)

	High	Mid-Range	Low
Congestion	$181,635	$61,761	$16,352
Crash Costs	$839,463	$339,886	$120,580
Air Pollution	$349,100	$40,443	$30,300
Noise	$11,446	$4,336	$1,214
Total	$1,533,344	$446,319	$170,246

Source: US DOT 2000.

and mortality, property damage, personal injury, and other costs associated with vehicle crashes, the total social costs of motor vehicle use in 2000 were estimated at between $170 billion and $1.5 trillion (U.S.DOT 2000).

If highway-user fees were designed to capture the full costs of highway use, the resulting revenue could be used to make investments (e.g., additional noise walls, improved clean fuel development, better air pollution control programs, development of new technologies, and better crash response teams) that could mitigate major portions of these external costs over time. Although some of the costs associated with these external cost categories are already internalized into highway agency budgets (e.g., emergency response costs and variable message signs), most social externalities are not being addressed through public expenditures. Because the remediation of external costs does not generally fall on a state's DOT, these costs are not allocated under the traditional expenditure-based HCAS approach in many states.

Substantial uncertainties exist in the estimation of external costs, underscoring the need for caution in identifying the implications of including them when setting highway-user charges. However, much can be learned from analyses of non-agency costs of highway use. The analysis of external costs is based on principles of economic efficiency. Ultimately, if highway users are required to pay highway-user charges equal to the costs they impose on others, then trips that are valued less than these costs will not be made and overall societal benefits will be maximized.

INCLUSION OF INTERNAL COSTS NOT INCLUDED IN AGENCY EXPENDITURES

We use the term "internal costs" to include all costs of highway-related programs and use of highways that show up in public expenditures during any time period. This is to distinguish such costs from "external" or "social" costs, which are discussed in the previous section. Internal costs can be divided into at least four categories, each of which could be considered in comprehensive HCASs.

The most obvious category of internal highway costs is current highway agency budgets and programmed expenditures, such as construction, maintenance, operations, and related administrative costs. These are almost always included in HCASs, except that federal expenditures on federal lands and similar expenditures on streets and highways that are not the responsibility of the state highway agency are often excluded from state HCASs. Although these may not be the direct responsibility of state highway agencies, excluding them could result in a less than complete analysis of highway expenditures in the state.

The next most closely related category of internal highway costs is state expenditures for highway-related programs that are not the responsibility of the state highway agency, such as the MVA, highway patrol, public transportation operations on streets and highways, crash response, traffic-related court costs, and highway-user fee tax collection and enforcement. Sometimes these expenditures are incurred by agencies in other parts of state DOTs, sometimes in other state agencies, and sometimes in agencies at other levels of government. Nevertheless, their exclusion results in less of a comprehensive analysis of expenditures on streets and highways.

The third category of internal highway costs are those that can be expected to occur in the future but are not already programmed, such as the costs of deferred maintenance. These are important costs because they are usually going to be significantly greater than the cost savings from cutting current maintenance program recommendations, so they could be included in HCASs even if they are not in adopted programs or budgets. In a typical HCAS, approved capital programs cover five to 10 years in the future, but maintenance programs, or at least routine maintenance, are often excluded from anything beyond current budget years. Often in the process of developing proposed future capital programs states will forecast future maintenance program requirements based on projections of future factors such as future lane-miles of highways and future maintenance costs per lane-mile. If deferred maintenance costs are likely to result in a significant increase in future maintenance costs per mile of highway, these costs should be included in an HCAS.

The fourth and final category of internal highway costs are those associated with potential expansions of highway systems beyond those included in all of the previous categories. Traditionally, these have been identified in "highway needs studies," which have typically included such potential future expenditures as upgrading portions of the highway system to include new routes, bypasses, and conversion of older routes to freeway standards. Such potential future expenditures have traditionally never been included in state HCASs, except during the early years of the development of the Interstate highway system. If a state wishes to give serious consideration to such a program, HCASs could include them when sufficient planning work has been done to provide both cost estimates and user forecasts.

ISSUES IN DEVELOPING RECOMMENDATIONS FOR CHANGES IN STATE TAX STRUCTURE

Experience demonstrates that state HCASs seldom if ever result in major changes in the tax structure owing to the importance of changes in tax burden to the stakehoders. As noted in the final paragraph of chapter four: "One issue in planning HCASs that often affect the likelihood of implementation is the stated set of conditions for studies." Examples were cited of ways in which HCASs have eased the pain of recommended changes in tax structure by either ensuring that no major changes in tax rates will occur or that any significant increase in taxes or fees will be done in a less painful way by seeking to reach agreement on quid pro quos.

A related approach that is sometimes done to ease pain in making changes in tax structure in related situations is to either stage the changes over a several year period or to just propose incremental changes at the completion of a study and defer further changes until the results of the next study are available.

Another way of incrementally improving the equity of the tax structure is to introduce some graduation of fees based on annual mileage in a state as distinct from establishing a tax that varies directly with mileage. Examples include having high-mileage vehicles pay higher weight fees or higher registration fees. A different approach used by a few states is setting a higher diesel tax rate for high-mileage vehicles.

A final way of coping with these important practical limitations is to propose small changes in tax structure targeted at the most seriously inequitable parts of the tax structure, such as by gradually reforming weight fees for very overweight permit vehicles or vehicles that should be subject to special weight fees (see the section in this chapter covering weight fees and other special fees). This was the approach taken in developing recommendations in the 1990 Vermont HCAS and in a follow-up analysis of special vehicles in 1991.

CHAPTER SIX

CONCLUSIONS

State Highway Cost Allocation Studies (HCASs) have a long history in the United States, with in excess of 80 studies being performed in at least 30 states over the past 70 years. Historically, the HCAS has been an effective tool in building equity into the state transportation tax structure. Equity is an essential element to consider when designing an effective transportation tax structure.

The principles underlying the HCAS continue to evolve even as fewer studies have been done in recent years. Many advances have been made and others proposed but not implemented in state HCASs. Therefore, states are faced with an expanding set of choices when conducting HCASs and are challenged with the importance and relevancy of equity considerations in state transportation tax structures.

This study was designed to aid states by laying the foundation required to build on current thought and improve current HCAS methods. Further, this synthesis highlights the importance of continuing the HCAS tradition and the consideration of equity in highway and related tax structures.

Most importantly, this study is designed to assist states that are considering performing an HCAS but have not performed a recent HCAS or have never performed one. Through a survey and literature review, it has become apparent that the need for HCASs continues today as states examine new ways of funding highway and related programs in response to constraints on the growth of motor fuel taxes through market penetration of hybrids and alternative fuels, inflation, and enhanced motor fuel economy, and considering new alternatives for addressing complex highway transportation issues.

Respondents to the survey that was completed as part of this synthesis raised a wide range of issues concerning the conduct of an HCAS and the following suggestions were among those offered:

- Allow adequate time (12 to 24 months) to conduct a thorough and accurate HCAS. Ensure that budget and staffing resources are adequate and dedicated with certainty to completing the HCAS. This recommendation is particularly important for states with little or no experience in conducting HCASs.
- Meet with staff in other states to understand what level of resources will be required and to develop an understanding of how the HCAS process will work.
- Identify problems inherent in the HCAS process through discussions with other state practitioners with more experience in conducting HCASs and design steps to work around these issues before they become a problem.
- Allocate a significant amount of up-front time and budget to planning the study. Planning efforts should include the determination of vehicle classes, time frame examined within the study, data needs, and staff assignments.
- When a contractor is hired to do the study, require a detailed scope of work and project schedule before the work begins. Clearly specifying expectations up-front is desirable because HCASs are extremely complex and misunderstandings can lead to cost overruns.
- Consider assembling a team of in-house experts (Department of Motor Vehicle staff, highway engineer, traffic data expert, bridge engineer, finance expert, maintenance engineer) to provide technical expertise in support of the HCAS. Forming this team of experts will enhance the accuracy of the study and streamline data collection efforts.
- Consider forming a study review panel comprised of external interested parties, including members of academia, highway users, local government, legislative staff, and industry. Forming such a group can expose issues that might not otherwise be brought to the attention of the examiners and encourages political acceptance of the report. (This group would serve in an advisory capacity and not be used to determine allocation procedures or establish parameters for the study.)
- Conduct HCASs regularly, ideally every 5 to 10 years. Dated HCASs tend to be viewed as obsolete as a result of changes in tax structures, traffic volumes, and highway programs. Conducting HCASs more frequently than recommended could lead to significant shifts back and forth in study results owing to short-term analysis periods in which impacts of highway or bridge construction programs are too sensitive to a small number of projects, resulting in increased volatility in recommended tax rates.
- Consider using existing software such as the State HCAS Model prepared by the FHWA. The issues that require attention in applying this model are well documented and the model is designed to allow extensive modification to meet specific needs at the state level. Further, the model has been tested and successfully applied at the state level. When developing an HCAS model ensure that you receive a commitment from information technology staff for support.

- Consider excluding evasion from HCASs. The use of evasion estimates in setting tax rates and attributing revenue often complicates HCASs and can be used to discredit HCAS results. Evasion studies are extremely complicated and often have not been successful in yielding reliable results.
- A true picture of equity would dictate that all user taxes and fees be considered in the equity ratio numerator, regardless of how they are spent, and all roadway expenditures, regardless of the source of the revenues, be included in the denominator. It is important to know not only if there is relative equity among highway users but also whether they are subsidized or are subsidizing other government functions.
- In conducting HCASs and considering what expenditures or costs not included in agency budgets should be included, the basic question is whether each expenditure is either necessary to build, maintain, or operate a highway system, or whether it is a necessary supporting service for highway programs. If expenditures or other costs are required for items to support the highway system such as rest areas, noise walls, highway patrol and police traffic control, traffic courts and driver education programs, crash response and incident management programs, some portions of public medical and air quality control programs, and some public transit investments, these could appropriately be allocated to highway-user classes.
- Examine and consider allocating the full social costs of highway use, including costs related to congestion, air pollution, noise, and vehicle crashes not covered by agency budgets. These costs are borne by society, and including them in HCASs results in a more comprehensive study. To the extent that relevant fees imposed as a result of such studies result in small adjustments to traveler behavior, the practice would serve to improve highway transportation system efficiency. When considering whether to include external costs, consider the data limitations, the inability of user fees to remediate damage, and other cautions noted in this report.
- At a minimum, federal and state expenditures for highway-related programs, regardless of funding source, and highway-user revenues, regardless of their use, should be included in the cost allocation and revenue attribution processes and analyzed separately, regardless of how the results may be combined for reporting purposes. There are several good reasons for including federal revenues and federal expenditures, including the increasing flexibility in the use of federal funds in recent years, as well as that federal funds are heavily used for expenditures on Interstate highways and other major highways that would otherwise require additional state expenditures. Include the results in a more thorough analysis of equity. If federal and/or local expenditures are included in the HCAS, then federal and/or local highway user revenues should also be included in the study for similar reasons.

Those surveyed for this study identified many other functions that HCAS products can perform in addition to addressing the question of equity between broad vehicle classes. These functions include:

- Responding to questions from legislators, state DOT policy makers, and others on issues related to the equity of a state tax structure;
- Analyzing the equity and related impacts of legislative proposals that require the state DOT's review;
- Analysis of issues dealing with the impact of proposals for changes in truck weight limits;
- Analysis of the impacts on cost responsibility of substantial proposed changes in the highway construction program;
- Responding to questions about the mix of vehicle classes using any classes of the state's highway system; and
- Responding to equity questions arising from emerging types of systems such as area-wide tolling, high-occupancy toll lane networks, and public-private partnerships.

Survey respondents offered the following suggestions for further research:

- Further develop and refine the FHWA State HCAS model, correct errors identified in Appendix C, and update with improved documentation and more extensive vehicle class data for the entire highway system.
- Perform additional research into emerging HCAS issues, including tolling, public-private partnerships, regional and interstate cooperation, and allocation of external costs (e.g., congestion, incident management, air and noise pollution).
- Conduct a thorough examination of alternatives for improving state HCAS practice, including methods for expanding the number of states performing HCASs, enhancing funding for future HCASs, and improving the implementation of HCAS results.
- Prepare selected issue papers dealing with both the organization of HCASs and their implementation, as well as more specific technical issues involved in conducting HCASs, perhaps some of them similar to those completed in support of recent Oregon HCASs.

REFERENCES

1999 Highway Cost Allocation Study, Nevada Department of Transportation, Carson City, Sep. 1999.

1999 Update of the Arizona Highway Cost Allocation Study, Final Report, Report FHWA-AZ99-477(1), Arizona Department of Transportation, in cooperation with U.S. Department of Transportation, Federal Highway Administration, Phoenix, Aug. 1999.

2002 Idaho Cost Allocation Study, Idaho Department of Transportation, Boise, 2002.

Blincoe, L., et al., *The Economic Cost of Motor Vehicle Crashes, 2000*, Prepared for the National Highway Transportation Safety Administration, Washington, D.C., May 2002, 94 pp.

Cambridge Systematics, Inc., Sydec Inc., and Pacific Rim Resources, *Oregon Weight-Mile Tax Study,* Prepared for the Oregon Legislative Revenue Office, Salem, Feb. 1996.

Carey, J., *1999 Update of the Arizona Highway Cost Allocation Study*, FHWA-AZ99-477(1), Prepared for the Arizona Department of Transportation, Phoenix, 1999.

Carey, J., *Implementation of the Simplified Arizona Highway Cost Allocation Study Model,* FHWA-AZ-01-477 (3), Prepared for Arizona Department of Transportation, Phoenix, 2001.

ECONorthwest with Jack Faucett Associates, HDR, Inc., and R.D. Mingo and Associates, *Highway Cost Allocation Study: 2005–2007 Biennium,* Prepared for Office of Economic Analysis, Oregon Department of Administrative Services, Portland, 2005.

ECONorthwest, *Highway Cost Allocation Study: 2007–2009 Biennium,* Prepared for Office of Economic Analysis, Oregon Department of Administrative Services, Portland, 2007.

Euriat, M., *Texas Highway Cost Allocation Analysis and Estimates, 1993–1995,* Prepared for Texas Department of Transportation, Austin, 1994.

Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., *Addendum to the 1997 Federal Highway Cost Allocation Study Report*, May 2000.

Federal Highway Cost Allocation Study Final Report, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., Aug. 1997.

Final Environmental Impact Statement for the Central Phoenix/East Valley Corridor, Phoenix, Ariz., Nov. 2002.

Final Environmental Impact Statement for the Central Phoenix/East Valley Corridor, U.S. Department of Transportation, Federal Transit Administration, and Regional Public Transportation Authority, Phoenix, Ariz., Nov. 2002.

Jacoby, A.C., *A Preliminary Pennsylvania Highway Cost Allocation Study,* Prepared for the State Transportation Advisory Committee, Pennsylvania Department of Transportation, University Park, Feb. 16, 1990.

Jack Faucett Associates with ECONorthwest, *2001 Oregon Highway Cost Allocation Study, Volume III: Specifications*, Prepared for the Office of Economic Analysis, Oregon Department of Administrative Services, Portland, 2001.

Luskin, D., A. Garcia-Diaz, D. Lee, Z. Zhang, and M. Walton, *A Framework for the Texas Highway Cost Allocation Study,* Research Report 0-1810-1, Prepared for the Texas Department of Transportation, Austin, Jan. 2001.

Luskin, D., A. Garcia-Diaz, D. Lee, M. Walton, Z. Zhang, *Texas Highway Cost Allocation Study,* Research Report 0-1810-2, Prepared for the Texas Department of Transportation, Austin, Oct. 2002.

Maine Highway Cost Allocation Study: Final Report, Maine Department of Transportation, Bangor, Feb. 1989.

McCubbin, D.R. and M.A. Delucchi, *The Annualized Social Cost of Motor-Vehicle Use in the U.S., Summary of Theory, Data, Methods, and Results,* Institute of Transportation Studies, University of California, Davis, 1998.

Oregon Legislative Assembly, Senate Joint Resolution 44, Salem, 1999.

Osborne, M., J. Pigman, and E. Thompson, *2000 Highway Cost Allocation Updated,* Performed for Kentucky Transportation Cabinet, Kentucky Transportation Center, University of Kentucky, Lexington, Mar. 2000.

Result of the Minnesota Highway-User Cost Allocation Study, Minnesota Department of Transportation, St. Paul, Oct. 1990.

Schrank, D.L. and T.J. Lomax, *The 2005 Urban Mobility Report,* Texas Transportation Institute, Austin, May 2005, 91 pp.

Schultz, J., "National Weight-Distance Tax Study Recommended by GAO in New Report," *Traffic World,* June 1994.

Selle, B., *Vermont Highway Cost Allocation Study*, Memo Provided to Highway Transportation Committee and House Ways and Means Committee of the Vermont Legislature, Montpelier, Jan. 2006.

Sinha, K., S. Saha, T. Fwa, A. Tee, and H. Michael, *1988 Update of the Indiana Highway Cost Allocation Study,* Final Report, FHWA/IN/JHRP-89/4, Prepared for School of Civil Engineering, Joint Highway Research Project, Purdue University, Indiana Department of Transportation, Mar. 1989.

Stowers, J., P. Balducci, R. Mingo, and H. Cohen, *Oregon Highway Cost Allocation Study: Issue Papers,* Prepared for the Department of Administrative Services, Salem, Sep. 1998.

Stowers, J., A. Reno, P. Balducci, R. Mingo, H. Wolff, H. Cohen, and D. Haling, *Oregon Highway Cost Allocation Study,* Prepared for the Department of Administrative Services, Salem, June 1, 1999.

Sydec Inc., Cambridge Systematics, Inc., and R.D. Mingo and Associates, *Cost Allocation Study Audit,* Final Report,

Submitted to Nevada Department of Transportation, Carson City, Sep. 1994.

Sydec, Inc., *Draft Guidelines for State Highway Cost Allocation Studies Using Excel Spreadsheet Software: Appendix A—Example of Maintenance Cost Allocation Factors*, Prepared for the Federal Highway Administration, Washington, D.C., Apr. 2000.

Sydec, Inc., R.D. Mingo and Associates, H. Cohen, and H. Wolff, *Highway Cost Allocation Study and Recommendations for Restructuring of Trailer Fees and Weight Fees*, Report to Legislature submitted to California Department of Transportation, Sacramento, May 1999.

Wheeler, P.K., "Transportation Cost Allocation: Applying Cost Allocation in a Multimodal Environment," *Transportation Research Record 1558*, Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 8–15.

BIBLIOGRAPHY

1981 Highway Cost Allocation Study, Final Report, Colorado State Highway Commission, Colorado Department of Highways, Denver, Oct. 1981.

1992 Motor Vehicle Cost Responsibility Study: Final Report and Technical Appendum, Oregon Department of Transportation, Salem, July 1993.

Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., May 2000.

Banks, F., *State Highway Cost Allocation Methods,* Highway Cost Allocation Study Working Paper Number 15, Prepared for U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., Mar. 1982.

Beshers, E., *External Costs of Automobile Travel and Appropriate Policy Responses,* Prepared for Highway Users Federation, Washington, D.C., 1994.

Bisson, B., J. Brander, and J. Innes, "Highway Cost Allocation Methodology for Pavement Rehabilitation and Capacity-Related Costs Occasioned by an Increment of Heavy Truck Traffic," *Transportation Research Record, 1038*, Transportation Research Board, National Research Council, Washington, D.C., 1985, pp. 10–16.

Boile, M., K. Ozbay, and P. Narayanan, *Infrastructure Costs Attributable to Commercial Vehicles,* Prepared for New Jersey Department of Transportation, Piscataway, Dec. 2001.

Bramlett, K. and M. Johnson, *State Highway Cost Allocation Studies*, U.S. Department of Transportation, Washington, D.C., Nov. 1983.

Castano-Pardo, A. and A. Garcia-Diaz, "Highway Cost Allocation: An Application of the Theory of Nonatomic Games," *Transportation Research Part A: Policy and Practice,* Vol. 29, No. 3, Washington, D.C., 1995.

Cohen, H., *Incorporation of External Cost Considerations in Highway Cost Allocation,* Interim Report, BATG-93-009, Prepared for U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1994.

Cost Responsibility Blue Ribbon Committee: Final Report, Oregon Department of Transportation, Salem, Feb. 1997.

Deacon, J., J. Pigman, and N. Stamatiadis, *Review of Highway Cost Allocation Methodologies,* Research Report KTC-92-6, Kentucky Transportation Center, University of Kentucky, Lexington, June 1992.

Delaware Highway Cost Allocation Study, Delaware Department of Transportation, Division of Planning, Bureau of Economic Research, University of Delaware, Dover, Mar. 1992.

Final Report on the Federal Highway Cost Allocation Study, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1982.

Fwa, T., K. Sinha, and S. Saha, "Update Analysis of Highway Cost Allocation," *Transportation Research Record 1262*, Transportation Research Board, National Research Council, Washington, D.C., 1990, pp. 1–11.

Garcia-Diaz, A. and A. Villarreal-Cavazos, "Two Alternative Approaches to the Highway Cost Allocation Problem," *Proceedings of the North American Pavement Conference,* Vol. 1, Ontario, Canada, 1985.

Gittings, G.L. and B.R. Narayan, "Federal Highway Revenue Estimation: Cost Allocation Perspective," *Transportation Research Record 1558*, Transportation Research Board, National Research Council, Washington, D.C., 1996.

Greene, D., D. Jones, and M. Delucchi, *The Full Costs and Benefits of Transportation: Contributions to Theory, Method and Measurement,* Springer Press, New York, N.Y., 1997.

Hajek, J., S. Tighe, and B. Hutchinson, "Allocation of Pavement Damage Due to Trucks Using a Marginal Cost Method," *Transportation Research Record 1613*, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 50–56.

Henion, L. and J. Merriss, "An Equity Assessment of Federal Highway Users Charged," *Transportation Research Record 967*, Transportation Research Board, National Research Council, Washington, D.C., 1984, pp. 24–31.

Henion, L. and R. Munford, *Advantages of Weight-Distance Taxes*, Presentation Before the Weight-Distance Tax Meeting, Phoenix, Ariz., Dec. 1990.

Hicks, A., A. Mokhtee, G. Comstock, R. McReynolds, and K. Stodgell, *Kansas Highway Cost Allocation Study,* Topeka, Sep. 1985.

Highway Cost Allocation Study Activity Report, Highway Subcommittee on Highway Transport, American Association of State Highway and Transportation Officials, Harrisburg, Pa., Feb. 1989.

Highway Cost Allocation Study, Division of Planning, Highway and Transportation Department, Missouri Department of Transportation, Jefferson City, Nov. 1984.

Highway Cost Allocation Study, Division of Planning, Highway and Transportation Department, Missouri Department of Transportation, Jefferson City, Nov. 1999.

Highway Cost Allocation Study, Final Report, Department of Transportation, State of Wisconsin, Madison, 1982.

Institute of Urban and Regional Research, University of Iowa, *Impact Analysis of a Cost-Based Approach to Highway Financing in Iowa,* Ames, Mar. 1984.

Jones, J. and F. Nix, *Survey of the Use of Highway Cost Allocation in Road Pricing Decisions,* Transportation Association of Canada, Ottawa, ON, Canada, 1995.

Laman, J. and J. Ashbaugh, "Fatigue Impacts on Bridge Cost Allocation," *Transportation Research Record 1624*, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 16–27.

Lee, D., *Full Cost Pricing of Highways,* Prepared for U.S. Department of Transportation, Washington, D.C., 1994.

Lemaire, J., "An Application of Game Theory: Cost Allocation," *Astin Bulletin*, Vol. 14, No. 1, Brussels, Belgium, 1984, pp. 61–81.

Mansour, N. and J. Semmens, *The Value of Arizona's State Highway System: A Corporate-Style Financial Analysis,* Prepared for the Arizona Department of Transportation, Phoenix, Sep. 1999.

Merriss, J., *New Research on Pavement Damage Factors,* Policy Notes, Oregon Department of Transportation, Salem, June 2003.

Oregon Cost Responsibility Studies Compared to Other States, Legislative Revenue Office Research Report #4-96, Oregon Legislative Revenue Office, Salem, Sep. 1996.

Parry, I., *Should Fuel Taxes be Scrapped in Favor of Per-Mile Charges*? RFF DP 05-36, Discussion Paper Prepared for Resources for the Future, Washington, D.C., Aug. 2005.

Result of the Minnesota Highway-User Cost Allocation Study, Minnesota Department of Transportation, St. Paul, Minn., Oct. 1990.

Rillett, L.R., B.G. Hutchinson, and R.C.G. Haas, "Cost Allocation Implications of Flexible Pavement Deterioration Models," *Transportation Research Record 1215*, Transportation Research Board, National Research Council, Washington, D.C., 1989, pp. 31–42.

Samson, T., *Surface Transport Costs and Charges: Great Britain,* Institute for Transport Studies, University of Leeds, United Kingdom, 2001.

Selle, B., *Additional Information on the Vermont Highway Cost Allocation Study*, Memo Provided to Highway Transportation Committee and House Ways and Means Committee of the Vermont Legislature, Montpelier, Jan. 2006.

Sinha, K. and T. Fwa, "A Highway Cost Allocation Analysis at the State Level," *Transportation Quarterly*, Vol. 41, No. 3, July 1987.

Straus, S. and J. Semmens, *Estimating the Cost of Overweight Vehicle Travel on Arizona Highways,* Prepared for Arizona Department of Transportation, Phoenix, Jan. 2006.

Stephens, J., T. Barth, and W. Cloud, *Cost Allocation Study for the Montana State Highway System,* prepared for Montana Department of Highway Research Program in cooperation with U.S. Department of Transportation, Federal Highway Administration, Helena, July 1992.

Sydec Inc., *California Highway Cost Allocation Study: Technical Report,* Washington, D.C., July 1987.

Sydec Inc., Cambridge Systematics, Inc., and R.D. Mingo and Associates, *Highway Cost Allocation Study,* Prepared for Arizona Department of Transportation, Washington, D.C., July 1991.

Sydec Inc., Cambridge Systematics, Inc., and R.D. Mingo and Associates, *Highway Cost Allocation Study,* Supplemental Report, submitted to Vermont Legislative Council, Montpelier, Feb. 1993.

Sydec Inc., Cambridge Systematics, Inc., and R.D. Mingo and Associates, *Highway Cost Allocation Study*, Final Report, Submitted to the Idaho Department of Transportation, Feb. 1994.

Task Force on Motor Carrier Taxation, Final Report and Technical Addendum, Oregon Department of Transportation, Salem, Jan. 1987.

Torbic, D., L. Elefteriadou, L.T. Ho, and Y. Wang, "Passenger Car Equivalents for Highway Cost Allocation," *Transportation Research Record 1576*, Transportation Research Board, National Research Council, Washington, D.C., 1997, pp. 37–45.

Urban Institute and Sydec Inc., *Rationalization of Procedures for Highway Cost Allocation Studies: Final Report*, Prepared for the American Trucking Associations, Washington, D.C., 1990.

Weisman, J., R. Reed, and A. Feroze, "Incremental Bridge Construction Costs for Highway Cost Allocation," *Transportation Research Record 1460*, Transportation Research Board, National Research Council, Washington, D.C., 1994, pp. 19–24.

Zongzhi, L., S. Kumares, and P. McCarthy, "Methodology to Determine Load- and Non-Load-Related Shares of Highway Pavement Rehabilitation Expenditures," *Transportation Research Record 1747*, Transportation Research Board, National Research Council, Washington, D.C., 2001.

ACRONYMS

ADT	Average daily traffic
AMT	Axle miles of travel
DMV	Department of Motor Vehicles
ESAL	Equivalent single-axle load
GVW	Gross vehicle weight
HCAS	Highway cost allocation study
HOT	High-occupancy toll
IT	Information technology
NAPCOM	National Pavement Cost Model
NTIS	National Technical Information Service
NTL	National Transportation Library
PCE	Passenger car equivalent
PPP	Public-private partnership
RGW	Registered gross weight
SMHCAS	Simplified Model for Highway Cost Allocation Studies in Arizona
STIP	Statewide Transportation Improvement Program
TIUS	Truck Inventory and Use Survey
TRIS	Transportation Research Information Services
VMT	Vehicle-miles of travel
VTrans	Vermont Agency of Transportation
VIUS	Vehicle Inventory and Use Survey
WIM	Weigh-in-motion

GLOSSARY

Alternative fee—a fee that is charged to some vehicles in place of the usual fee (e.g., a lower registration fee for publicly owned vehicles).

Arterial—a road or highway used primarily for through traffic.

Attributable costs—costs that are a function of vehicle size, weight, or other operating characteristics and therefore can be attributed to vehicle classes based on those characteristics.

Average daily traffic—average number of vehicles passing a given point or using a given highway per day.

Average daily truck traffic—average number of trucks passing a given point or using a given highway per day.

Axle-miles of travel (AMT)—product of VMT multiplied by the number of axles. Because trucks, on average, have roughly twice as many axles as cars (i.e., four versus two), their share of the total AMT on any given highway system will be approximately double their share of VMT on that system.

Axle weight or axle load—gross load carried by an axle.

Beltway—a controlled-access arterial encircling an urban area.

Collector—a road that connects local roads with arterial roads.

Common costs—expenditures that are independent of vehicle size, weight, or other operating characteristics and so cannot be attributed to any specific class of vehicles. These expenditures must therefore be treated as a common responsibility of all vehicle classes and are most typically assigned to all classes on the basis of a relative measure of use such as VMT.

Cost allocation—the analytical process of determining the cost responsibility of highway-system users.

Cost-occasioned approach—one that determines responsibility for highway expenditures/costs based on the costs occasioned or caused by each vehicle class. Such an approach is not based solely on relative use, nor does it attempt to quantify the benefits received by different classes of road users.

Cost responsibility—based on the principle that those who use the public roads should pay for them and, more specifically, that payments from road users should be in proportion to the road costs for which they are responsible. It is the proportionate share of highway costs legitimately assignable to a given vehicle class user group.

Cost-based approach—one in which the dollars allocated to the vehicle classes are measures of the costs imposed during the study period, rather than expenditures made during the study period. The difference between the cost-based and expenditure-based approaches is most evident when considering large investments in long-lived structures and when deferred maintenance moves the costs associated with one period's use into another period.

Cross-subsidization—a condition where some vehicles overpay and others underpay relative to their respective responsibilities.

Dead load—load on a bridge when it is empty.

Debt financing—funding current activities by issuing debt to be repaid in the future.

Debt service—funds used for the repayment of previously incurred debt (both principal and interest).

Deck—the roadway or surface of a bridge.

Depreciation—the amount of decrease in the value of a physical asset owing to aging in a time period.

Efficiency—the degree to which potential benefits are realized for a given expenditure.

Efficient pricing—a system of setting prices for the use of highway facilities so that each vehicle pays the costs it imposes at the time and place it is traveling. It promotes the most efficient use of existing facilities and generates the right amount of revenue to build the most efficient system and perform the optimal amount of maintenance.

Equity—generally interpreted as the state of being just, impartial, or fair. Horizontal equity refers to the fair treatment of individuals with similar circumstances. Vertical equity refers to the fair treatment of individuals in different circumstances.

Equity ratio—the ratio of the share of revenues paid by a highway-user group to the share of costs imposed by that group. A user group that meets 110% of its cost responsibility would be assigned an equity ratio of 1.1. Equity ratios above 1.0 are assigned to user groups who are paying more than their cost-responsible share, where payments from user groups assigned equity ratios of less than 1.0 fall short of the costs imposed by the group.

Equivalent single-axle load (ESAL)—are calculated based on the pavement stress imposed by a single axle with an18,000-lb axle load. ESAL-miles are equivalent single-axle loads times miles traveled. Research has concluded that the relationship between axle weight and ESALs is an approximate third- or fourth-power exponential relationship; ESALs therefore rise rapidly with increases in axle weight.

Excise tax—a tax levied on the production or sale of a specific item such as gasoline, diesel fuel, or vehicles.

Expenditure—the amount of money spent in a time period.

External cost—one imposed on individuals who do not use the facility.

Federal highway funds—those collected from federal highway-user fees and distributed to states by the FHWA for spending on transportation projects by state and local governments.

Functional classification—a system of classification of roads according to their general use, character, or relative importance. Definitions are provided by the FHWA for Rural Interstate, Rural Other Principal Arterial, Rural Minor Arterial, Rural Major Collector, Rural Minor Collector, Rural Local, Urban Interstate, Urban Other Expressway, Urban Other Principal Arterial, Urban Minor Arterial, Urban Collector, and Urban Local.

Functionally obsolete—a functionally obsolete bridge is one that no longer meets minimum standards, but may continue to operate with load restrictions.

Gross vehicle weight—the loaded weight for a vehicle.

Highway cost allocation study (HCAS)—a study that estimates and compares the costs imposed and the revenues paid by different classes of vehicles over some time period.

Highway Performance Monitoring System—a system whereby the FHWA collects and reports data about a sample of road segments in every state in a common format.

Highway user—a person responsible for the operation of a motor vehicle in use on highways, roads, and streets. In the case of passenger vehicles, the users are the people in the vehicles. In the case of goods-transporting trucks, the user is the entity transporting the goods.

Incremental cost—the additional costs associated with building a facility to handle an additional, heavier (or larger) class of vehicle.

Incremental method—one that assigns responsibility for highway costs by comparing the costs of constructing and maintaining facilities only for the lightest class of vehicles and for each increment of larger and heavier vehicles. Under this method, vehicles share the incremental cost of a facility designed to accommodate that class as well as the cost of each lower increment.

Light (or basic) vehicles—the lightest vehicle class, usually including passenger cars, vans, and pickups.

Live load—the additional load on a structure by traffic (beyond the dead load imposed by holding itself up).

Load-related costs—those costs that vary with the load imposed by traffic on a facility.

Marginal cost—the increase in total cost that results from producing one additional unit of output. With respect to highway use, the marginal cost is the increase in total highway costs that results from one additional vehicle trip. Economic efficiency is achieved when the price charged to the user is equal to the marginal cost.

National Highway System—a set of highways throughout the United States that have been designated as national highways by the federal government. The FHWA sets design and maintenance standards and provides funding for national highways; however, the highways are owned by the states.

National pavement cost model—a model of pavement costs that incorporates the wear-and-tear costs imposed by vehicle traffic of different weights and configurations as well as deterioration from age and environmental factors, taking into account the soil type, road-base depth, pavement material, pavement thickness, and climate zone.

Non-divisible load—large pieces of equipment or materials that cannot be feasibly divided into smaller individual shipments. All states issue special permits for non-divisible loads that would otherwise violate state and federal gross vehicle weight, axle weight, and bridge formula limits.

Operating weight—the actual weight of a vehicle at a particular time.

Overhead costs—costs that vary in proportion to the overall level of construction and maintenance activities, but are not directly associated with specific projects.

Passenger car equivalent—a measure of road space effectively occupied by a vehicle of a given type under given terrain, vehicle mix, road type, and congestion conditions. The reference unit is the standard passenger car operating under the conditions on the road category in question.

Registered weight—the weight that determines the registration fee paid by a single-unit truck or a tractor. For a tractor, it is typically the highest of that vehicle's declared weights.

Revenue attribution—the process of associating revenue amounts with the classes of vehicles that produce the revenues.

Right-of-way—the strip of land, property, or interest therein, over which a highway or roadway is built.

Seismic retrofit—the work done on an existing structure intended to increase its resistance to earthquakes.

Social (or indirect) costs—costs that highway users impose on other users or on non-users. Costs typically included in this category are those associated with noise, air, and water pollution; traffic congestion; and injury and property damage resulting from traffic accidents.

Span—a section of a bridge.

State highway system—comprises all roads under the jurisdiction of state agencies.

Statewide Transportation Improvement Program—a program where each state, following federal law guidelines, produces and regularly updates a list of intended future transportation improvements.

Structurally deficient—one that fails to meet the desired level of structural integrity. Weight limits often are placed on structurally deficient bridges.

Tax avoidance—the legal avoidance of a tax or fee.

Tax evasion—the illegal failure to pay a tax or fee.

Truck—a general term denoting a motor vehicle designed for transportation of goods. The term includes single-unit trucks and truck combinations.

User charge—a fee, tax, or charge that is imposed on facility users as a condition of usage.

User revenues—highway revenues raised through the imposition of user charges or fees.

Value pricing—a system where prices are set in proportion to the benefits or value received by road users.

Vehicle class—any grouping of vehicles having similar characteristics for cost allocation, taxation, or other purposes. The number of vehicle classes used in a cost responsibility (allocation) study will depend on the needs, purpose, and resources of the study. Potential distinguishing characteristics include weight, size, number of axles, type of fuel, time of operation, and place of operation.

Vehicle miles of travel—equal the sum of vehicles divided by the number of miles each vehicle travels within a time period.

Vehicle registration fees—fees charged for being allowed to operate a vehicle on public roads.

Weight-mile tax—a graduated fee based on the weight of a vehicle and the miles the vehicle travels.

APPENDIX A

State Highway Cost Allocation Study Survey

This questionnaire and the compilation of the survey results are an important part of a synthesis of Highway Cost Allocation Study (HCAS) experiences in recent years. Under the direction of Gail Staba of the Transportation Research Board, this synthesis is being performed by Patrick Balducci of Battelle and assisted by Joseph Stowers of Sydec, Inc. Their contact information is provided at the end of this questionnaire. They welcome your questions or contacts at any time.

The purpose of state-level HCASs is to determine the fair share that each class of road user should pay for the construction, maintenance, operation, improvement, and related costs of highways, roads, and streets in the state. Through a comparison of user fees paid and cost responsibilities, these studies estimate current equity and may provide recommended adjustments to existing user fees and tax rates to bring about a closer match between payments and cost responsibilities for each vehicle class.

Over 30 state governments have at some time conducted these studies to evaluate their system of state road-user charges, fees, and taxes. Studies vary in depth and scope. To date, results have been mixed. This synthesis will compare and contrast what has been completed by various states and seek to provide guidance for future studies based on this experience.

Both federal and state highway agencies utilize HCASs to evaluate their revenue systems and to maintain a cost-based user system because

- It promotes equity: The users of a highway system that utilizes cost-based finance pay for what they use.
- It encourages cost-effective use of the road system: Users respond to the costs they face, and may choose vehicle types, intensity, patterns of use, and other factors in response to these assigned costs.
- It fosters financial sustainability and/or self-sufficiency: By linking cost to user charges, a cost-based system generates revenues needed to develop and maintain the required road system.

States have adapted a wide variety of techniques and conventions to estimate highway use and the payment of user fees by vehicle classes. All states and user groups would benefit from a review and comparison of the highway cost allocation methods. This review is particularly important at this time because states are considering new or enhanced revenue sources to meet needs. New transportation technologies and revenue initiatives add opportunities and uncertainty.

Please note that in Part I of the questionnaire we ask for contact information for possible follow-up questions, and we ask for each state's consideration of using multiple contacts if that is appropriate. Also note that we are asking for responses to a few questions from states that have never conducted an HCAS.

<u>Part I</u> **Responsibility for Highway Cost Allocation Studies (HCASs) and Related Work**

(a) What unit of your agency is responsible for HCASs and related work?

_____

(b) What person in that unit is currently responsible and/or is the best contact person?

_____ Telephone: _____ E-mail address: _____

(c) Are other units of your agency or other agencies responsible for parts of such studies or for closely related work? Please consider obtaining response(s) to one or more questions from other important contacts.

Organization: _____ Contact information: _____

Other:_____ Contact information: _____

(d) Person(s) responding to this questionnaire:_____

Contact information: _____

Contact information: _____

Part II **Highway Cost Allocation Studies Completed or Planned**

(e) Has your state performed an HCAS since 1982?

☐ Yes Please continue with question (f)

☐ No Please skim the questions that follow and respond if appropriate, then answer questions (s) and (x) in Part III

(f) Dates of HCASs performed since 1982 (date of a major benchmark Federal HCAS report) in your state:

_____ _____ _____ _____ _____

(Please list years of most recent HCAS-related reports completed.)

(g) Were any of these reports status reports, updates rather than complete new studies, procedural or methodology reports, etc.?

_____

(h) Did your state complete any major benchmark HCASs or related work prior to 1982?

_____

What was the special importance of that (those) effort(s)?

_____

(i) In your state's most recent HCAS, what levels of government were separately analyzed in terms of source of funds versus cost responsibility?

☐ State funds and state highways only

☐ State and federal funds combined only

☐ State and federal funds analyzed separately

☐ State, federal, and local funds analyzed separately

☐ Other: _____

(j) Were any of your state's previous HCASs different in terms of the levels of government separately analyzed?

☐ Yes (please specify below.)

☐ No

Year of Study					
_____	_____	_____	_____	_____	
☐	☐	☐	☐	☐	State funds and state highways only
☐	☐	☐	☐	☐	State and federal funds combined only
☐	☐	☐	☐	☐	State and federal funds analyzed separately
☐	☐	☐	☐	☐	State, federal, and local funds analyzed separately
☐	☐	☐	☐	☐	Other: _____

(k) Have any of your HCASs included analyses of unmet needs, the long-term costs of deferred maintenance, etc.? If so, please provide a brief description of what was done and contact information:

_____

(l) Have any of your HCASs involved consideration of costs to users versus costs to non-users? If so, please provide a brief note on what was done and any available citation:

_____

(m) Have any of your HCASs involved consideration of non-user taxes and fees to support highway transportation? If so, please provide a brief note on what was done and any available citation:

_____

(n) Please provide links to any reports noted within this section if available, or send a copy of each report to the name and return address listed at the end of this questionnaire.

(o) Please identify any consultants that were responsible for each of these studies or portions of the studies:

Name: _____ Year: _____

Responsibilities: _____

Contact Information: _____

Name: _____ Year: _____

Responsibilities: _____

Contact Information: _____

(p) Please list any special surveys or major data collection efforts done as part of HCASs:

_____

(q) Please estimate the approximate cost and/or level of staff effort required for these studies.

_____

Part III **Questions Related to Highway Cost Allocation Studies**

(r) Were the HCASs done as an initiative of the state's DOT? ☐ Yes ☐ No

As an initiative of other agencies? ☐ Yes ☐ No

By mandate or request of the legislature or other officials? ☐ Yes ☐ No

(s) Why were the studies done? (Check as many boxes as appropriate.)

- ☐ To determine whether the state's taxes and fees were equitable
- ☐ To adjust tax and fee rates to be more equitable
- ☐ To respond to questions raised by
  - ☐ legislature
  - ☐ governor
  - ☐ others
- ☐ Other: _____

If none were done, why not?

- ☐ Lack of technical expertise or experience
- ☐ Too costly and time-consuming
- ☐ No issues have arisen calling for such studies
- ☐ Other: _____

(t) What has been the impact of the HCASs? (Check as many boxes as appropriate and add comments to clarify as desired.)

- ☐ Helpful in developing recommendations for changes in user fees or tax rates: _____
- ☐ Effective in getting support for improvements in the equity of the tax structure in the legislature and/or other officials: _____
- ☐ Helpful in planning other related work: _____
- ☐ No impact: _____
- ☐ Other: _____

(u) Are you aware of any recent efforts to extend HCASs to include analysis of externalities such as those listed below? If so, please check appropriate boxes and provide relevant information on type of effort and contacts.

- ☐ Congestion: _____
- ☐ Air pollution: _____
- ☐ Noise: _____
- ☐ Health and damage (injuries, fatalities, loss of productivity and property damage): _____
- ☐ Other: _____

(v) Are you aware of any recent work being done that might be helpful in extending HCASs to deal properly with emerging new approaches? If so, please provide relevant information on type of effort and contacts. _____

- ☐ Highway finance: _____
- ☐ Public-private partnerships: _____
- ☐ Toll systems: _____
- ☐ High-occupancy toll lane systems: _____
- ☐ Other: _____

(w) Optional question; all responses will be kept strictly confidential with no attribution to specific states. Would you be willing to make a brief assessment of the quality of your state's most recent HCASs, perhaps pointing out strengths and shortcomings, if any? Please rate the work from (1) Excellent, to (2) Good, to (3) Average, to (4) Needs Improvement or Has Some Weaknesses, to (5) Not Successful, Poor, or Caused More Problems Than It Solved. Provide strengths and shortcoming or any elaboration on your responses in the space following each topic name.

1	2	3	4	5	
☐	☐	☐	☐	☐	Technical methods and data: _____
☐	☐	☐	☐	☐	Accuracy of the methods: _____
☐	☐	☐	☐	☐	Credibility of work among the stakeholders: _____
☐	☐	☐	☐	☐	Coverage of vehicle classes, etc.: _____
☐	☐	☐	☐	☐	Coverage of all relevant funding sources, fees, and taxes: _____
☐	☐	☐	☐	☐	Handling of important special revenue factors, such as tax- or fee-exempt or partially-exempt vehicles: _____
☐	☐	☐	☐	☐	Other: _____

(x) What would be most helpful to you in terms of planning and conducting future HCASs? (Please check as many boxes as appropriate.)

- ☐ Improved guidelines: _____
- ☐ Copies of previous HCAS reports from other states: _____
- ☐ Software: _____
- ☐ Conference(s), networking, and/or federal workshops: _____
- ☐ Other: _____

Please add any advice you may have for states considering, or about to start, an HCAS:

_____

Part IV **Thank you for completing this questionnaire! Please return it and any reports [see Part II (N) above] by March 9 to:**

Patrick Balducci
Senior Economist
Battelle Memorial Institute
620 SW 5th Avenue
Portland, Oregon 97204
Phone: (503) 238-7483
Fax: (503) 238-7501
Cell: (503) 679-7316
Balduccip@Battelle.org

Other Important Contact Information:

Gail R. Staba, AICP
Senior Program Officer
Airport Cooperative Research Program
National Cooperative Highway Research Program
Transportation Research Board
The National Academies
500 Fifth Street, NW
Washington, D.C. 20001
Phone: (202) 334-2116
Fax: (202) 334-2081
Cell: (415) 305-5380
gstaba@nas.edu
www.trb.org

Joseph Stowers
President, Sydec, Inc.
1612 Washington Plaza N.
Reston, Virginia 20190
Phone: (703) 742-0707
Fax: (703) 742-0790
Home phone: (703) 437-3870
Sydec@Patriot.net

APPENDIX B

Summary of Survey Results

Part I. Background Information

(a) What unit of your agency is responsible for HCASs and related work?

	Responses
Planning & programming unit	13
Financial unit	4
1 & 2 combined	1
Policy unit	1
1 & 4 combined	1
Other unit	7
Multiple units	1
Total	28

Part II. Highway Cost Allocation Studies Completed or Planned

(e) Has your state performed an HCAS since 1982?

	Responses
Yes	19
No	14
Total	33

(f) HCASs performed since 1982 (date of a major benchmark Federal HCAS report) in your state.

	Responses	States
States performing one study only	9	Alaska, Delaware, Florida, Kansas, Maryland, New Mexico, New York, Pennsylvania, Wyoming
States performing two studies	6	California, Idaho, Missouri, Montana, Virginia, Wisconsin
States performing three studies	0	
States performing four studies	1	Vermont
States performing five studies	2	Kentucky, Arizona

States performing more than five studies	2	Oregon (15), Nevada (6)
Total states	20	
Total studies	56	

(h) Did your state complete any major benchmark HCASs or related work prior to 1982?

	Responses	States
Yes	6	New York, North Carolina, Oregon, Virginia, Washington, Wyoming
No	24	
Total	30	

(i) In your state's most recent HCAS, what levels of government were separately analyzed in terms of sources of funds versus cost responsibility?

	Responses
State funds and state highway only	5
State and federal funds combined only	8
State and federal funds analyzed separately	1
State, federal, and local funds analyzed separately	3
Other: state, federal, and local funds combined only	2
Total	19

(k) Have any of your HCASs included analyses of unmet needs, the long-term costs of deferred maintenance, etc.?

	Responses
Yes	3
No	16
Total	19

Comments related to Question (k):

1.	Nevada: Unmet needs, yes. Deferred maintenance, no. Our 10-year transportation plan was used to analyze future construction needs. We assumed that all those projects would be funded, even though funding at the time was inadequate to do so. We also assumed that preservation work would be fully funded and based our future needs on our biennial State Highway Preservations Reports.

2.	North Carolina: North Carolina used it to justify a bond issue in the 1970s.
3	Oregon: The 1974 and 1980 studies analyzed alternative expenditure levels beyond the base (expected expenditure level based on existing tax rates) budget.

(l) Have any of your HCASs involved consideration of costs to users versus costs to non-users?

	Responses
Yes	0
No	18
Total	18

(m) Have any of your HCASs considered non-user taxes and fees?

	Responses	States
Yes	4	California, Idaho, Nevada, Oregon
No	14	
Total	18	

(p) Please list any special surveys or major data collection efforts done as part of HCASs:

	Responses
Special surveys of local governments' highway expenditures by type	5
Updated financial data and ran reports	1
Weigh-in-motion (WIM), vehicle configurations	1
Traffic, registered vehicles, weight-mile data	2
Local government expenditure allocation survey	1
Special truck weight studies	1
Studded tire damage studies	1
Flat fee studies	1
Pavement, bridge, and interchange cost responsibility studies	1
Total	14

Comments related to Question (p):

1.	Arizona: Updated financial data and ran reports
2.	California: Local government surveys for each HCAS
3.	Idaho: WIM and vehicle configurations

4.	Montana: Significant effort in compiling traffic data and compiling registered vehicle information
5.	Nevada: Routine HPMS data collection for traffic; special analyses of miles traveled, ESAL-miles traveled, and ton-miles traveled by various vehicle classifications
6.	Oregon: Local government survey; special truck weight survey; studded tire studies; flat fee study; pavement, bridge, and interchange cost responsibility studies
7.	Virginia: A special survey was done to obtain (vehicle weight * VMT data); it was referred to as the "summer survey" in the 1991 study report
8.	Wisconsin: Special study of axle weights by registered vehicle weight class

(q). Please estimate the approximate cost and/or level of staff effort required for these studies.

	Responses
Under $100,000	3
$100,000–$200,000	2
$200,000–$350,000	1
$350,000–$500,000	4
4–5 person-months	2
5-man task force, 3 years	1
A few days of in-house staff time	1
Total	14

Part III. Questions Related to Highway Cost Allocation Studies

(r) What entity initiated the demand for an HCAS?

	Responses
HCASs done as an initiative of the state's DOT	14
As an initiative of other agencies	0
By mandate or request of the legislature of other officials	11
Total	25

(s) Why were the studies done?

	Responses
To determine if taxes and fees were equitable	26
To adjust taxes and fee rates to be more equitable	12
To respond to questions raised by others:	(13)
Legislature	11
Governor	0
Other (California: requirement of 1991 ISTEA)	2
Total	51

If none were done, why not?

	Responses
Lack of technical expertise or experience	1
Too costly and time consuming	2
No issues have arisen calling for such studies	8
Other	1
Total	12

(t) What has been the impact of the HCASs?

	Responses
Helpful in developing recommendations for changes in user fees or tax rates	13
Effective in getting support for improvements in the equity of the tax structure in the legislature and/or with other officials	3
Helpful in planning other related work	5
No impact	4
Other	4
Total	29

Comments related to the "other" response in Question (t):

1.	Florida: Impact unknown at this time.
2.	Kansas: The study was helpful during development of the Comprehensive Highway Program to verify the equity of user fees between vehicle classes.

3.	Nevada: The studies provided detailed understanding of tax laws and tax collection to aid in making substantive and effective changes in tax collection (e.g., reducing evasion, developing an on-line oversize/overweight permit system, and improved customer service by moving highway-fund tax collections to a single agency).
4.	Oregon: This was particularly important in the 1980s and early 1990s when a series of legislative measures were successful in raising Oregon's fuels tax rate from 7 cents to 24 cents per gallon and increasing the truck tax rates proportionately to maintain the proper, cost-responsible balance of payments from light and heavy vehicles.
5.	Virginia: The 1991 HCAS promoted interest in development of more precise tools and data collection/storage systems for use in periodic cases, as well as legislative action to increase user fees on the motor carrier sector. A subsequent study (1992) was commissioned to evaluate pavement deterioration methodologies, propose better data management, and examine tax equity proposals for motor carriers. Interest declined between 1992 and the present.

(v) Are you aware of any work extending HCASs to deal with emerging new approaches?

	Responses
Highway finance	2
Public-private partnerships	1
Toll systems	1
High-occupancy toll lane systems	0
Other:	3
Total	7

Comments related to the "other" response in Question (v):

1.	Arizona: Any new revenue sources should be attributed to vehicle classes paying them, with costs attributed to vehicles that occasion them
2.	Oregon: Monitoring a Road-User-Fee Task Force Pilot Program currently testing the feasibility of using a mileage-based fee to eventually replace the fuels tax in Oregon
3.	Virginia: Distributions of truck operating weights for given registered weights might be available from WIM data

(w) Please rate the quality of your state's most recent HCAS.

	Excellent	Good	Average	Weak	Poor
Technical; methods and data	1	6	3	0	0
Accuracy of the methods	2	6	2	0	0

Credibility of work among stakeholders	2	4	1	3	0
Coverage of vehicle classes	2	4	3	1	0
Coverage of all relevant funding sources, fees, and taxes	3	4	3	0	0
Handling of special revenue factors	1	4	4	1	0
Total	11	28	16	5	0

(x) What would be most helpful to you in conducting future HCASs?

	Responses
Improved guidelines	15
Copies of HCAS reports from other states	18
Software	15
Conference(s), networking, and/or federal workshops	14
Other	13
Total responses	75

Comments related to the "other" response in Question (x):

1.	Arizona: If you cannot afford to conduct full-fledged HCASs on a frequent basis (at least once every five years) you should consider using a simplified methodology. As time passes, older HCASs can be criticized or dismissed as "obsolete" given new traffic and new construction.
2.	California: AASHTO should consider recommendations to guide states considering future HCASs and related studies.
3.	Idaho: Before starting study, contact other states to establish guidelines for study and develop understanding of the process, don't rely on consultants alone. The state must have a deep understanding of the process and potential outcomes before beginning.
4.	Michigan: Engineering knowledge about the effect of trucks with Michigan's weight limits.
5.	Montana: Assure you have adequate staffing resources and access to the data you need before you start. Not having good quality data can be extremely dangerous.
6.	Nevada: Legislative action consistent with the study results to motivate us to conduct additional studies. If the study results will be ignored, don't conduct one. It's too big an effort to satisfy your curiosity. However, if you believe it will be a valuable tool for progress (whether in terms of developing equitable tax policy, building better traffic information, or exposing significant data collection or analysis weaknesses), then the rigors are worth it. you have adequate staffing resources and access to the data you need before you start. Not having good quality data can be extremely dangerous.
7.	Ohio: Ohio would just refer to national studies or studies from other states.

8.	Oregon: Allow adequate time for completion of the study and any follow-up analyses requested by state administrators, legislators, legislative staff, etc. Also ensure the staff resources and budget for the study are adequate, particularly for a first-time effort that will tend to be more costly than a continuing effort. Talk to/meet with staff in other states that have done such studies to get an informed idea of what will be required, what data sources will be needed, problems likely to been encountered, potential ways to work around these problems, how best to present the study results, and gain political acceptance for these results, etc. Devote a significant amount of up-front time to planning the study, including determining exactly what issues the study is to address and what questions it will be designed to answer; deciding on the vehicle classes to be analyzed and which expenditures and revenues to include; preparing a list(s) of the numerous data elements that will be required and determining whether the data are available and, if so, from where and how long it will take to be obtained; and deciding whether it will be more cost-effective to do the study in-house or have it performed by consultants (although there are exceptions, as a general rule, a state considering doing a first-time HCAS will often find it preferable to rely on consultants). If the study is contracted out, require that the selected contractor provide a detailed work plan and projected schedule before beginning any actual work on the study. These studies tend to be costly and it is very important that the potential for any misunderstanding of what is expected of the contractor be minimized right from the beginning by clear and effective communication. If doing the study in-house, prior to the actual commencement of work on the study, form a technical advisory team composed of internal, subject-matter experts (e.g., a pavement engineer, a bridge engineer, a maintenance engineer, an agency budget officer, etc.) to provide guidance and technical expertise for the study. This will pay great dividends when it comes time to ask these same individuals for data, analyses, or other information required for the study. Regardless of whether the study will be done in-house or by consultants, also form (again, prior to commencement of work on the study) a study review or advisory group composed of external stakeholders and other interested parties (e.g., a representative of the state trucking association, a representative of the automobile association, a representative of local governments, one or two academics, subject-matter experts from local universities, and a legislative staff person or even a couple of selected legislators such as the chairs of the committees dealing with transportation and revenue matters). Forming such a group and having them meet on a regular basis to advise on and provide guidance for the study will not guarantee political acceptance of the study results and recommendations, but it will most certainly help in this regard. If this type of group becomes too large, however, it can become cumbersome, dysfunctional, and actually work to discourage rather than encourage political acceptance of the study results. It is therefore recommended such a group be kept relatively small—10 to 15 members is in most cases the ideal size.
9.	Utah: UDOT is interested in the results of this synthesis report.

10.	Vermont: Assemble a team of people representing the areas of expertise required for a successful HCAS. For VTrans, that included the Budget Office, DMV staff, Highway Research, and Traffic Research. The effort had high level support from the Directors because it was required by the legislature for the 2006 session. If possible, use existing software. VTrans found that the free FHWA HCAS software covered our needs. Regarding the FHWA software: - Review the Vermont recommendations that were submitted to the FHWA that outlines some of the problems to watch out for. - Run the software with the default data to make sure it works in your environment. - Get a commitment from the IT staff for support. - Run the system frequently as you add expenditure and revenue information. Make sure that all input is accurately reflected in the output reports. Frequent execution of the system makes i it easier to diagnose problems. The legislature requested the HCAS study; however, it had little effect on the final fee bill. I testified about the study at the House Ways & Means Committee, the House Transportation Committee, and the Senate Transportation Committee. VTrans wanted fees that would hit trucks harder, but that is politically sensitive. Several legislators commented that increases in truck fees would simply be passed on to Vermont consumers. Additionally, they did not want Vermont to get out of line with the surrounding states of New Hampshire, New York, and Massachusetts. Several fee proposals were discussed. We ran HCAS with the increased revenue and reported on which class of users would pay. We were surprised at the differences in equity rations (1.27 for two-axle vehicles and 0.55 for trucks. Light vehicles are over paying, and heavy vehicles are underpaying.) Our approach was reviewed by a consultant, Joe Stowers of Sydec, and we feel the results are accurate. One possible reason for the truck underpayment is that the VTrans' budget is heavily dependent on federal funding (55%); therefore, the expenditure side of the equation is tilted toward truck corridors, NHS and Interstate. Trucks get more benefit in the VTrans programs. Also, our rural state does not have expensive congestion mitigation expenditures that would fall primarily on automobiles. Someone representing the trucking industry was at each testimony session; however, I am not aware of any behind-the-scenes trucking industry participation in the process. We diligently tried to apply the correct allocation rules and fine-tune the tables so that we could defend the system if necessary. The final results, however, were not very sensitive to many of the rules in the FHWA HCAS. (Arizona's simplified HCAS approach is of interest to us if we conduct another study.) There were no challenges to the HCAS results. Most of the legislative debate centered on the VTrans/DMV proposal to reduce the amount of money transferred from the Transportation Fund to the Education Fund. (The final bill reduced the Education Fund transfer and raised numerous DMV fees.) The equity ratios moved only one percentage point towards equity for both light and heavy vehicles.

	I estimate the study took about four to five person months of effort including working with the software. Another study would be easier now that we know what to collect and what is important. Although the project was completed by inhouse staff, we had a consultant review our approach, meet with several agency staff, and fix a software problem.
11.	Virginia: FHWA Office of Policy can provide a state highway cost allocation tool on CD-ROM that was developed by consultants. Could be very useful if a state's data are compatible with the tool.
12.	Washington: No future HCASs are planned.
13.	Wyoming: Improved documentation from FHWA for the software they developed. More extensive vehicle class data for the entire state highway system.

APPENDIX C

VTrans Issues with Federal Highway Administration State Highway Cost Allocation Study Software

Excerpts from a letter from Bart Selle, State of Vermont to Joseph R Stowers, Sydec, Inc., dated November 28, 2005.

Vermont is successfully running FHWA's State Highway Cost Analysis System (HCAS). This letter describes the problems we encountered, and suggests improvements to the HCAS software. Problems are:

1. Directory location of the programs CostAlloc, Rev&Tables, and DefaultData:
   The documentation recommends placing the HCAS software in the Excel default directory; however, users still might get an error if they open HCAS from the Excel most-recently-used-file list. One solution is to always navigate to the HCAS spreadsheet from Excel.
2. *Rev&Tables* file names in the *BasicQuestions* worksheet:
   Is there a reason why the user must change the file names in the *BasicQuestions* worksheet? Could the file names be synchronized with actual names on the FHWA CD? That would facilitate testing HCAS "out of the box."
3. *CostAlloc* state code in *2H AllocationFactorsState*:
   Six state codes generate a Visual Basic "Run-time Error 13." Sydec fixed the problem for VT, but I believe the problem still exists for other states.
4. *Rev&Tables* Other Permits (Cell D22) in *1B StateRevControls* worksheet:
   The "light vehicle" Other Permits cell cannot be zero (Cell D22). A small value solves the problem.
5. *Rev&Tables* vehicle miles traveled information in *1F UserRevenueData* worksheet:
   Vermont collects VMT information on 12 vehicle classes. We do not allow large doubles or triples on Vermont highways; however, zeros for the DS7 vehicle type generates a visual basic error. The solution is to enter a small value such as 0.00001 for the DS7s.
6. *Rev&Tables* diesel tax rate in *2D LocalTaxRates* worksheet:
   The diesel tax rate value (cell C9) cannot be zero, or it will generate a visual basic error. A zero triggers an "N/A" entry in the tax evasion cells starting at C32. That alpha data causes a VB error in later calculations. The solution is to put in a very small number in cell C9.
7. *CostAlloc* traffic fatality information in the *4F MiscCostData* worksheet:
   HCAS does not seem to use the traffic fatality information. To test it, I entered large numbers in the thousands, but it had no effect on the result. If it is not needed, HCAS should not ask for it.
8. *Rev&Tables* state tax rates in *2B StateTaxRates* worksheet:
   It's not clear where the tax rate information is used. It seems to have no effect on the results. Revenue comes from the *1B StateRevControls* worksheet. It is not calculated from the tax rates.
9. *CostAlloc* operating gross weight in the *4C OGWDist* worksheet:
   We calculated operating-gross-weight-by-vehicle-type from Vermont WIM data, and replaced the default OGW table. If the weight ranges in the new table do not exactly match the default weight ranges, the user will get "Bad (vehicle type code)" warning messages when executing the *CalcRGOG* on the *2H AllocationFactors* worksheet. Although it is just a warning message, it would be helpful if it were documented.
10. "#REF" in *1F UserRevenueData* in *Rev&Tables*:
    The table starting at cell BR60 has "#REF" in all the cells. It doesn't seem to adversely affect anything, but it is a distraction. You provided a fix for Vermont's version, but that fix should be put in the FHWA version, too.
11. *Rev&Tables* report options *in 2G TableSpec:*
    "Option 1" reports on 12 vehicle types, but it produces incorrect results on the cost side. The costs in Table 4 are shifted and have different values when compared to the correct costs in Table 3. Use "Option 2" for 20 vehicle types instead.
    "Option 5" and "Option 7" for operating-gross-weight reports do not allocate the correct expenditure amount. "Option 3" appears to work OK.

Other advice to a new HCAS user is

- Run the system exactly as delivered by the FHWA to prove that it works in your environment.
- Run the system whenever anything changes. Frequently reconcile the revenue and costs reports to the source worksheets. Problems are much easier to track if you haven't changed much since the last successful execution.
- Be very careful when deleting or zeroing out cells. If you inadvertently hit a space key, subsequent programs might generate a visual basic error. (A "space" and "delete" look the same.)
- Many options do not have a significant impact on the results. Determine how sensitive the results are before spending excessive time refining data.

Run HCAS on the fastest processor available. It will consume 100% of the cycles when executing.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
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	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
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
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation