# AN INVENTORY OF SELECTED MATHEMATICAL MODELS RELATING TO THE MOTOR VEHICLE TRANSPORTATION SYSTEM

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September 1978

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UM-HSRI-78-28

**Technical Report Documentation Page**

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|---|---|---|
| 1. Report No. UM-HSRI-78-28 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle An Inventory of Selected Mathematical Models Relating to the Motor Vehicle Transportation System | | 5. Report Date September 1978 |
| | | 6. Performing Organization Code |
| 7. Author(s) B.C. Richardson, K.B. Joscelyn, D.H. Golomb, M.M. Luckey, L.D. Segel | | 8. Performing Organization Report No. UM-HSRI-78-28 |
| 9. Performing Organization Name and Address Policy Analysis Division Highway Safety Research Institute The University of Michigan Ann Arbor, MI 48109 | | 10. Work Unit No. |
| | | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address Motor Vehicle Manufacturers Association 300 New Center Building Detroit, MI 48202 | | 13. Type of Report and Period Covered Final 6/77-6/78 |
| | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes | | |

16. Abstract

This volume presents an inventory of seventy-eight selected mathematical models (econometric, physical, accounting, etc.) relating to the motor vehicle system. The models included describe some impact on society and/or the environment and may have the potential for use in policy-related analyses. Each model is described in a format giving its objectives, limitations and benefits, structure, data and computer requirements, documentation, and other relevant information. Indexes are included which may be used to identify models according to name, authors, sponsors, and type. Subject areas covered by the models include: automobile demand, fuel consumption and economy, air pollution, market share, modal split, and vehicle miles traveled.

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|---|---|---|---|
| 17. Key Words modeling, fuel consumption, econometric, mathematical models, motor vehicle system, automobile demand | | 18. Distribution Statement Unlimited | |
| 19. Security Classif. (of this report) Unclassified | 20. Security Classif. (of this page) Unclassified | 21. No. of Pages 293 | 22. Price |

ACKNOWLEDGEMENTS

The cooperation of many individuals has made this study possible. Their contributions are gratefully acknowledged.

A number of Highway Safety Research Institute staff were indispensable in the preparation of this report. Howard M. Bunch, Beverly K. Roth, and James D. Tomola wrote inventory reports for several of the models. Kathleen B. Weber and Ann C. Grimm of the HSRI Information Center obtained many of the reports needed in preparing this document and coordinated with project staff in the performance of the computer-based literature searches. Sherry K. Birtley, Elnora J. Crockett, Lois J. Ellis, Jacqueline B. Royal, Flora C. Simon, Frances E. Thomas, and Patricia L. Whichello each typed various parts of this report. Anne L. VanDerworp served as lead secretary on the project. Olga S. Burn coordinated the production of the report and was assisted by Martha A. Allison. Kathleen A. Jackson provided graphics support, and editing of the final draft was done by Natalie H. Lenaghan and James E. Haney. James H. Saalberg and Thomas C. Anderson performed a technical review of the entire report.

Lawrence E. Slimak and Christian van Schayk of the Motor Vehicle Manufacturers Association (MVMA) provided useful comments and suggestions, as did members of the MVMA Ad Hoc Committee on Federal Simulation Models that served as an advisory committee to this project. Committee membership includes Richard H. Shackson, chairman, Samuel M. Zentman, James H. Merritt, and James F. Marquardt. Alternate committee members are Neil E. South and Irene E. Szopo.

Several authors and sponsors of models provided valuable input to the study. Particularly helpful were Ronald A. Mauri, Robert C. Ricci, Ernest T. Kendall, and Charlotte A. Chamberlain of the Transportation Systems Center of the U.S. Department of Transportation and Carmen DiFiglio and Phillip D. Patterson of the Department of Energy.

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TABLE OF CONTENTS

# 1.0 INTRODUCTION

This volume presents an inventory of selected mathematical models (econometric, accounting, physical, etc.) relating to the motor vehicle system. These models, which describe some effect on society or the environment have been assembled because they are potentially useful in public policy related analyses, or because they have advanced the development of models pertaining to the motor vehicle system.

The inventory is a product of the second and third phases of a project entitled "An Analytical Study of Mathematical Models of the Motor Vehicle System," sponsored by the Motor Vehicle Manufacturers Association (MVMA) and conducted by the Highway Safety Research Institute at The University of Michigan. The work for this volume was done during the period March 1977 through June 1978. The project is to be a continuing one, and supplements to this first volume will be published periodically.

## 1.1 Project Background

The staff of the Highway Safety Research Institute in 1976 began an examination of mathematical models of the motor vehicle system, an effort that became the first phase of a larger project to report on mathematical models that have implications for policy making. Phase I of the study included the preparation of a brief inventory of models of the types used in the 1976 Federal Task Force Study of Motor Vehicle Goals Beyond 1980[1] (vehicle miles traveled, automobile demand, energy consumption, and vehicle dynamics). During Phase II of the study, the inventory was expanded by the addition of more model types and more examples of the types included in Phase I. In addition, models of particular interest were selected for analysis, and a plan developed for the third phase of the study. During Phase III, from July 1977 through June 1978, the expansion of the inventory continued, as did the analysis of selected models, and the investigation of the use of models in policy analysis.[2] The expansion of the inventory, the analysis of models, and the examination of their use are being continued.

## 1.2 Project Objectives

The general objective of the study has been to examine and describe mathematical models that have been, are currently, or could be used in formulating policy related to the motor vehicle system. The specific

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[1] U.S. Department of Transportation, The Interagency Task Force on Motor Vehicle Goals Beyond 1980, <u>The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980</u>, Draft, Sept. 2, 1976.

[2] Two reports on these topics are currently in preparation by HSRI staff: <u>Wharton EFA Automobile Demand Model: An Analysis</u>, and <u>Applications of Mathematical Models in Motor Vehicle System Policy Making: The Wharton EFA Automobile Demand Model - A Case Study</u>.

objectives have been to:

1) find, collect, and describe existing mathematical models of the motor vehicle system (that is, compile this inventory),

2) provide the capability for exercising selected models via computer,

3) analyze selected models,

4) exercise the models under alternative future conditions or scenarios,

5) modify and integrate models in response to specific requirements, and

6) investigate the use of models in policy formulation.

### 1.3 Report Organization

The purpose of this report--a product of the inventory task of the study--is to present succinctly and in a structured way useful information about policy-oriented models of the motor vehicle system. Section 1.0 describes the technical approach used to compile the inventory. Section 2.0 contains the individual reports on those models examined through June 1978. The third section indexes the models in five ways: according to author, sponsor, model type, model name, and accession number. The last of these, the Accession Number Index, summarizes the entire inventory of models; it gives the accession numbers, model names, authors, model types, and sponsors.

### 1.4 Technical Approach

The term "model" has been broadly used in this inventory. Any system of equations that is intended to represent a process or a system, such as the motor vehicle market, may be called a model. Taking this into account, the inventory includes models that consist merely of single equation, econometric regression specifications that were not intended to be used as policy evaluation tools when they were developed, and sophisticated programs with large data bases that have been developed specifically for policy analyses. The complex models are incuded here because they have the potential for being used in research and policy making, especially by the federal government. The simple models have been included because they are representative of research that has advanced economic theory as it applies to automobile demand, fuel or energy consumption, market share, vehicle miles traveled, or other aspects of the motor vehicle system.

Several steps were required to compile the inventory: models had to be (1) found, (2) screened and collected, (3) reviewed for their relevancy and classified by type, and (4) reviewed finally to extract the information for this report.

### 1.4.1 Finding the Models

Four sources were used to find relevant models: library catalogs, computer files, personal contacts with people in the field, and follow-up of references in reports on various models. All four sources proved to be necessary as each uncovered a number of models not discovered by any of the other three.

For the library search in this study, the catalogs of the libraries of The University of Michigan were searched by topic for titles suggestive of suitable literature. The materials stored at the Highway Safety Research Institute also were searched in this way. A library search is the most familiar way to find the literature on a given subject, but it is limited by the probable incompleteness of the catalogs, the possible narrowness or inappropriateness of the topic terms chosen for the search, and the potential biases of the searcher in the interpretation of a title or report.

The second search, repeated periodically, was of three computer-based files of literature: (1) the Transportation Research Information Service (TRIS) data base, sponsored by the U.S Department of Transportation and the Transportation Research Board, (2) the National Technical Information Service (NTIS) data base, and (3) the Compendex data base (Engineering Index). The latter two are accessible through the Lockheed DIALOG Retrieval Service. To find all potentially relevant models, the HSRI staff used broad search terms. Even so, several models previously known to be significant were not included in any of the citations produced by the computer file searches.

Having nonetheless compiled a considerable list of models using library and computer searches, the project staff made personal contacts their third search method. They contacted authors, sponsors, and users of some of the models by telephone, personal visits, or both. Their purpose was to elicit more information about each model: i.e., its logic, assumptions, structure, data requirements, and use. Their contacts included individuals in key divisions within the Department of Transportation, the Environmental Protection Agency, the Department of Energy, and other federal organizations.

Many of the reports on the models found by one of these methods referred to other models, including models typical of the state of the art, models that provide input to or use output from the subject model, and models which are extended or superseded by the subject model. The fourth method the staff used to compile the inventory, then, was to assemble information about additional models referred to in reports on other models. If these new models seemed germane, they were added to the inventory.

Every effort was made to be as comprehensive as possible, but nevertheless it is likely that some models were overlooked in the search process. Moreover, it is possible that some of the information obtained from representatives of sponsoring or model-using agencies or from authors was not always accurate and comprehensive. This is likely to have occured because of staff turnover, unpublished modification or uses of models, non-disclosure of proprietary information, or the unfamiliarity of some persons in large organizations with activities in other branches. Since supplements to this volume are to be published periodically, the authors would appreciate receiving any information the reader may have pertaining to new models of the type reported here or updates or corrections to the summaries of models included in this inventory.

### 1.4.2 Initial Screening and Collection

The models found by these search methods were screened initially for their appropriateness to the project by checking their complete names or titles and by reviewing abstracts when these were available. Models relating to the motor vehicle system were considered appropriate if they (1) described an effect on society or the environment, (2) were judged to be usable in policy-related analyses, or (3) had advanced the development of models pertaining to the motor vehicle system. Every effort was made by the project staff at this point to be as inclusive as possible.

In general, the staff concentrated their efforts on identifying models built after 1970. Some models written before then are included to illustrate the past state of the art, but no effort was made to compile a complete file of models built before 1970. The models included are generally of national, rather than local, applicability. However, several models that are based on local area data have been included primarily because they may be used in analyses of regions other than those on which they were based. Therefore, while there are travel-demand models included in this inventory, local mode-split models are not included because they are usually calibrated for specific regions and are not generally used in national policy making.

The model types included in this study are listed in Table 1.

The collection of models was done primarily in two ways: (1) by employing the usual acquisition procedures of the Highway Safety Research Institute library, and (2) by contacting model authors and sponsors and requesting that reports on the models, their programs, or whatever form of documentation was available be sent to the staff. The first method was used more extensively since it proved possible to obtain documentation on most models found during the library and computer searches by this means.

### 1.4.3 Initial Model Review

After receiving the documentation, the HSRI staff reviewed each model twice. The first review was to check the relevance of the model to the project and to classify it by type. The second review was more extensive and provided the information necessary to complete an inventory form for the model. At the time of initial review, if a model did not appear to be relevant to the study, it was eliminated from further consideration. If it did appear relevant, it was assigned an

TABLE 1: MODEL TYPES

| | |
|---|---|
| Accidents | Motorcycles |
| Air Pollution/Air Quality | National Economic Impact |
| Automobile Demand | Noise Pollution |
| Automobile Design | Pricing |
| Emissions | Scrappage |
| Energy Consumption | Trucks |
| Fleet Size | Vehicle Manufacturing Resource Utilization |
| Fuel Consumption | Vehicle Miles Traveled |
| Fuel Economy | Vehicle Operating Performance |
| Industrial Financial Performance | Vehicle User Costs/Vehicle Operating Costs |
| Market Share | Weight |
| Modal Split | |

accession number and cataloged by type. (The accession number is described in Section 2.0)

### 1.4.4 Completion of Inventory Forms

Once it was decided to include a model in the inventory and an accession number was assigned, the model report was reviewed again--in depth--to extract the information to be entered on inventory forms and to be included in this report. At this time information pertaining to models that was obtained from authors, sponsors, and users was also entered on the inventory forms. It must be noted, however, that the information reported for most models was derived solely from the model reports that are cited on the inventory forms. These forms were designed by the project staff to provide an overview of each model. They summarize information pertaining to each model, including its history, authors, structure, documentation, data requirements, and other key points. The completed inventory forms for those models reviewed are contained in Section 2.0.

### 1.5 The Indexes

In the third section of this volume, following the main body of the text, the models are indexed according to author, sponsor, model type, model name, and accession number. Each index gives the accession numbers by which the models are ordered in this inventory. In addition to serving as guides to the models in the inventory, the indexes may be used also to provide the reader with summary information on such matters as the types of models apparently in use by agencies of the federal government and others, and the frequency of model occurrence for each category of author, sponsor, and type.

## 2.0 INVENTORY REPORTS

This section contains the inventory reports of the relevant models assembled through June 1978. The reports follow a standard format with similar information about each model summarized under a consistent outline of categorical headings. For some models information is not provided under all headings either because the required information was unavailable or because the particular category of information was irrelevant to the model. The level of detail reported for each model is dependent, in large part, on the level of detail contained in the published documentation of the model. The following paragraphs describe the categorical headings used in the inventory forms.

Accession Number: Each model is assigned a five-digit accession number. The first two digits represent the year in which the model report was written and the last three the order in which the reports were received by HSRI project staff. It is the last three digits by which the models are ordered in this section. For example, 74-005 follows 75-004. If there are a small number of distinct submodels within a model, each submodel is further designated by appending a letter (i.e., A, B, C, etc.) to the five-digit accession number. A separate inventory form is included for each submodel to facilitate more complete and accurate reporting.

Although the reports on the models are ordered consecutively, there are gaps in the sequence of accession numbers. These gaps occur because some models proved to be duplicates or irrelevant during the in-depth review process. These were deleted from the inventory, but only after the accession numbers had been assigned.

Model Name: The model name refers to the commonly recognized name of the model if it has one. Otherwise, the name of the report in which the model is presented is listed.

Summary: The first paragraph of each report is a summary statement about each model, including its name, author, date, sponsor, purpose, and if documented, its use in policy analysis.

Sponsor: Included in this item are the name and address of the organization which sponsored the construction of the model. If there was more than one sponsoring organization, each of these is included.

Author: This designation includes the name and address of the organizational author of the model, and the name of each individual author, where these have been identified.

Model Type: Model type refers to the output which the model was built to produce, e.g., scrappage, fuel economy, vehicle miles traveled. All models are categorized into one or more of the several model types listed in Table 1.

Objective of Model: The objective of the model is the purpose for which the model was built. This often includes the relationships which are analyzed in the model.

Relationship to Other Models: The names of other models to which a model is related are listed. These include models of which submodels are components and other models which may be functionally related to the listed model.

Historical Background: Relevant history pertaining to the model, including the reasons for its development and any models which preceded it and constituted developmental antecedents, is summarized.

Assumptions: Basic assumptions made in the construction of the model, including primarily those reported by model authors, are indicated. These may include assumed relationships among variables, assumed substitutability of factors, and similar imposed conditions.

Validation: Validation includes any information relating to the forecasting behavior and dynamic properties of the model which have been reported by model authors or others. Forecasting behavior refers to comparing actual values with predictions of the model. Dynamic properties refer to the time paths of changes in the endogenous variables of the model in response to a change in one or more of the exogenous variables of the model.

Limitations and Benefits: Particular limitations or benefits of the model are indicated. Limitations may include the fact that a model is out of date or that the relative importance of variables has changed over time. Benefits might include a successful, innovative approach to a particular analytic problem.

Structure: Structure refers to the analytical structure of the model, including the model form or logic and the equations. If the equations of the model are numerous, representative equations or the key equations from the model are presented.

Model Construction: The data base used in the construction of the model is identified, if this information is appropriate and available. Data series and fit periods are indicated if available. If the model has not been estimated on historical data, the method of model construction is indicated.

Data Used in Running Model: The data bases which are required to run the model are listed.

Documentation: The sources for the information about the model are cited. Occasionally, more than one reference has been used or is available.

Computer Requirements: When available, information is provided pertaining to the computer requirements or specifications of the model including hardware, running time, programming language, etc.

Following are completed inventory reports for the 78 models encompassed in this study to date. It must be kept in mind that the information presented in these inventory reports is subject to change. During subsequent phases of this project, additional and up-dated information will be sought pertaining to the models presently included in the inventory. In addition, new models will be identified and incorporated into the inventory file. This new material will be included in supplements to this volume that will be published periodically in the future.

# GENERALIZED AUTOMOBILE DESIGN MODEL

The Generalized Automobile Design Model, dated October 1974, was prepared by the Rand Corporation for the National Science Foundation. The model assesses the effects on resources, energy requirements, and auto ownership costs of changes in either auto size, performance, or design.

## SPONSOR

Research Applied to National Needs (RANN)
National Science Foundation
Washington, D.C. 20550

## AUTHOR

T.F. Kirkwood and A.D. Lee
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Automobile design

## OBJECTIVE OF MODEL

The model assesses the effects of auto size, performance, or design on resources, energy requirements in the production of autos, and the cost of auto ownership.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Rand Automobile Energy Conservation Model, which includes the Automobile Fleet Mix Model (74-001B) and the New Car Sales/Auto Ownership/Vehicle Miles Traveled (NAV) Model (74-001C).

## HISTORICAL BACKGROUND

Most engine design simulation studies have modeled the effect on fuel economy when auto weight is reduced while engine size is held constant. This model holds auto performance constant; thus engine size would be reduced along with auto weight.

## ASSUMPTIONS

The model assumes that autos of equal weight have equal ride quality;

thus if technological improvements result in a change of weight, it will result in a change in ride quality. Each auto design produced by the model will have an engine with sufficient power to provide the desired acceleration, the auto body will have dimensions to include the desired size of passenger compartment, trunk, engine, and fuel tank, and the curb weight of the car will be the sum of the weight of its component parts.

## VALIDATION

Actual and predicted values of curb weight, overall length, installed horsepower, and fuel economy for twelve actual 1973 autos are very close.

## LIMITATIONS AND BENEFITS

The model can evaluate various design options, such as new engine types, tire design and pressure, aerodynamic design, new transmission types, new fuels, new materials, and changes in the sizes of passenger compartments and trunks.

## STRUCTURE

The model consists of a set of equations for keeping track of the effects of changes in component weights, performance, and cost, and for summing the effects of these changes on overall costs and energy consumption.

The outputs of the model include:

1) a description of a car, including weight, overall dimensions, installed horsepower, fuel economy over two driving cycles, and purchase price.

2) a list and weights of the materials necessary to produce the car.

3) a list of all the energy consumed in producing, distributing, selling, and operating the auto throughout its assumed lifetime of ten years and 100,000 miles.

4) a breakdown of the total cost of buying and operating the auto throughout its lifetime.

## MODEL CONSTRUCTION

The model was calibrated using actual data on the relationships between throttle power, transmission efficiency, engine rpm, road speed, auto weight, specific fuel consumption, engine rated power, and vehicle component weights.

## DATA USED IN RUNNING MODEL

To run the model the desired car dimensions, acceleration time, range without refueling, trunk volume, and air conditioning status must be supplied.

## DOCUMENTATION

S. Wildhorn, B.K. Burright, J.H. Enns, and T.F. Kirkwood, How to Save Gasoline: Public Policy Alternatives for the Automobile, Rand Corporation, prepared for the National Science Foundation, October 1974. NTIS No. PB-242 755.

T.F. Kirkwood and A.D. Lee, A Generalized Model for Comparing Automobile Design Approaches to Improved Fuel Economy, R-1562-NSF, Rand Corporation, Jan. 1975.

# AUTOMOBILE FLEET MIX MODEL

The Automobile Fleet Mix Model was prepared by the Rand Corporation. The model, dated October 1974, was sponsored by the National Science Foundation. The purpose of the model is to assess the impact of autos of new design or of reduced size on the characteristics of the overall fleet.

## SPONSOR

Research Applied to National Needs (RANN)
National Science Foundation
Washington, D.C. 20550

## AUTHOR

S. Wildhorn, B.K. Burright, J.H. Enns, and T.F. Kirkwood
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Emissions, vehicle user costs/vehicle operating costs, energy consumption, fuel consumption, fleet size, vehicle population

## OBJECTIVE OF MODEL

The objective of the model is to provide an assessment, by calendar year, of the impact on overall fleet characteristics of autos of new design or of reduced size that are introduced at specific rates.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Rand Automobile Energy Conservation Model, which includes the Generalized Automobile Design Model (74-001A) and the New Car Sales/Auto Ownership/Vehicle Miles Travelled (NAV) Model (74-001C).

## HISTORICAL BACKGROUND

The model was developed for three primary reasons: (1) previous studies were not comprehensive, (2) they did not compare price-change measures with measures that improve average auto fuel economy, and (3) they did not provide for the evaluation of alternative policy measures for inducing the adoption of beneficial technological changes.

## STRUCTURE

The mix of the auto fleet each year from 1975 to 1995 is determined with the use of the equation:

$$N_{wiy} = N_{wi(y-1)} + T_{wy} B_{wiy} P_y - \sum_{j=0}^{18} K S_j (T_w B_{wi} P_y)_y + N_{f(y-1)} (1 - K S_y)$$

where:

$N_{wiy}$ = number of autos in the fleet at the end of the year in weight class w with technological features i

$T_{wy}$ = fraction of the annual production (in year y) in weight class w

$B_{wiy}$ = fraction of the production (in year y) in weight class w with technological features i

$P_y$ = total annual production in year y

K = scrappage rate correction factor to allow for the difference between anticipated scrappage rates and those based on past experience

$S_j$ = fraction of autos of age j scrapped in their $j$th year

$N_{fy}$ = number of autos in the original fleet (i.e., the fleet existing at the start of 1975), remaining at the end of year y

$S_y$ = fraction of the original fleet retired in year y if retirement occurred at a rate typical of past experience

The total number of cars at the end of year y is obtained by summing over w and i.

Other equations are used to calculate fleet emissions, fleet fuel consumption, fleet scrappage rate, fleet annual cost, per vehicle annual cost of ownership, and fleet energy consumption.

## MODEL CONSTRUCTION

This is an econometric model whose production and scrappage rates in future years are estimated from the NAV Model (74-001C). Scrappage rates are estimated on the basis of past experience and the age distribution of the 1975 fleet.

DATA USED IN RUNNING MODEL

Forecasts of the independent variables are required for future year estimates.

DOCUMENTATION

S. Wildhorn, B.K. Burright, J.H. Enns, and T.F. Kirkwood, How to Save Gasoline: Public Policy Alternatives for the Automobile, Rand Corporation, prepared for the National Science Foundation, October 1974. NTIS No. PB-242 755.

T.F. Kirkwood and A. Lee, A Generalized Model for Comparing Automobile Design Approaches to Improved Fuel Economy, R-1562-NSF, Rand Corporation, Jan. 1975.

# NEW CAR SALES/AUTO OWNERSHIP/VEHICLE MILES TRAVELED (NAV) MODEL

The New Car Sales/Auto Ownership/Vehicle Miles Traveled (NAV) Model, dated October 1974, was prepared by the Rand Corporation for the National Science Foundation. The model forecasts changes in aggregate new car sales, auto ownership (new cars, used cars, cars scrapped), vehicle miles traveled, and gasoline consumption over time.

## SPONSOR

Research Applied to National Needs (RANN)
National Science Foundation
Washington, D.C. 20550

## AUTHOR

S. Wildhorn, B.K. Burright, J.H. Enns, and T.F. Kirkwood
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Automobile demand, fuel economy, fuel consumption, fleet size, vehicle miles traveled

## OBJECTIVE OF MODEL

The model forecasts changes in aggregate new car sales, auto ownership (new cars, used cars, cars scrapped), vehicle miles traveled, and gasoline consumption over time. It is a long-run impact model.

## RELATIONSHIP TO OTHER MODELS

This is a submodel of part of the Rand Automobile Energy Conservation Model, which includes the Generalized Automobile Design Model (74-001A) and the Automobile Fleet Mix Model (74-001B).

## HISTORICAL BACKGROUND

The model was developed for three primary reasons: (1) previous studies were not comprehensive, (2) they did not compare price-change measures with measures that improve average auto fuel economy, and (3) they did not provide for the evaluation of alternative policy measures for inducing the adoption of beneficial technological changes.

## ASSUMPTIONS

The model assumes that the prices of new cars and of gasoline are fixed outside the model. Thus the supply of gasoline for automobile travel is assumed to be perfectly elastic.

## VALIDATION

The model report compares actual and predicted values for the estimating period (1954-72), and for 1973. The model underpredicts new car sales by 3.5% and real used car prices by 8.7%.

## LIMITATIONS AND BENEFITS

The model cannot be used to forecast future market equilibrium. It is used to make conditioned forecasts of how American families would adjust to changes in prices of new cars and gasoline.

## STRUCTURE

The model is a recursive system estimated by ordinary least squares.

$$Pu = -0.8960 + 1.7268\ (Pn) - 0.87122\ (Pg) + 0.44809\ (Y) - 1.404\ (A_{-1}) - 0.029592\ (S),\ Pu > 0$$

$$N = -0.5080 - 0.20869\ (Pn) + 0.09318\ (Pu) + 0.73050\ (Y/Y_{-1}) + 0.01733\ (S)$$

$$U = -0.05894 - 0.26645\ (Pu) + 0.63665\ (Pn) - 0.59339\ (Pg) + 0.22529\ (Y) - 0.01186\ (S),\quad U \leq A_{t-1}$$

$$A = N + U$$

$$LE = 2.656 + 0.17015\ (LPg) - 0.02228\ (D)$$

$$LM = 7.996 + 0.86405\ (LA) - 0.44409\ (LPg) + 0.44409\ (LE) + 0.03532\ (D)$$

$$LG = LM - LE$$

where:

L = logrithmic value

Pu = index of real used car prices

Pn = index of real new car prices

Pg = index of real gasoline prices

Y = permanent income per household

A = this year's auto stock per household

$A_{-1}$ = last year's auto stock per household this year

S = dummy variable for strikes in auto manufacturing

N = annual new car sales per household

U = used car ownership per household

E = average miles per gallon in automobile travel

D = dummy for federal regulation

M = vehicle miles driven in automobiles per household

G = gasoline consumption by automobile per household

## MODEL CONSTRUCTION

This is an econometric model in which the equations for used car prices, new car prices, and used car ownership per household were estimated with annual data from 1954 to 1972. Those for average miles per gallon and vehicle miles traveled per household were estimated with annual data from 1956 to 1972. The sources of the data for the independent variables are indicated in the model report.

## DATA USED IN RUNNING MODEL

Forecast values for new car price, gasoline price, number of households, and permanent income are required.

## DOCUMENTATION

S. Wildhorn, B.K. Burright, J.H. Enns, and T.F. Kirkwood, How to Save Gasoline: Public Policy Alternatives for the Automoble, Rand Corporation, prepared for the National Science Foundation, October 1974. NTIS No. PB-242 755.

B.K. Burright and J.H. Enns, Economic Models of the Demand for Motor Fuel, Rand Corporation, R-1561-NSF, Jan. 1975.

# NEW PASSENGER CAR SALES AND MARKET SHARES MODEL

The Chase Econometric Associates, Inc. model of new passenger car sales and market shares was prepared in 1974 for the Council on Environmental Quality. The model forecasts new car sales, in total and by size class, annually through 1986 for six tax and regulatory alternatives. It has been superseded by a new model. The new model is proprietary and is not included in this inventory.

## SPONSOR

Council on Environmental Quality
722 Jackson Place, N.W.
Washington, D.C. 20006

## AUTHOR

Chase Econometric Associates, Inc.
One Chase Manhattan Plaza
New York, N.Y. 10015

## MODEL TYPE

Automobile demand, market share

## OBJECTIVE OF MODEL

The objective of the model is to forecast new passenger car sales, in total and by size class, through 1986 for six tax and regulatory alternatives.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel whose output is used in the gasoline consumption submodel (74-002B), which was also prepared by Chase Econometric Associates, Inc. as part of the same study. This model is used in conjunction with the Chase macroeconomic model.

## HISTORICAL BACKGROUND

An earlier version of the model did not include the relative price of gas as an independent variable because it had not proved to be significant before the Arab oil embargo. It was, however, included in the model for 1973.

ASSUMPTIONS

The new car sales equation of the model assumes that a four-quarter weighted average is appropriate for both disposable income and the stock of passenger cars, depreciated at the annual rate of 4.7%. The market shares equation assumes that reasonable estimates are produced, although the data vary significantly only when a new line of cars is introduced. The forecasts assume that relative prices and miles per gallon remain unchanged at the 1973 levels, except for the effects of 1975 and 1976 emission controls, as predicted in Hittman Associates, Inc., A Study of Industry Response to Policy Measures Designed to Improve Automobile Fuel Economy. The forecasts of shares by subclass were normalized to sum to 100% for each year by accepting the luxury share equation and assuming the following values for standard class share: 10% in 1974, 5% in 1975, and 0% thereafter. In effect, the forecast assumes that "full-size" cars will be reduced in size to the current (1974) intermediate car size and disappear as a distinguishable class.

VALIDATION

The model report does not discuss specific validation efforts for this model.

LIMITATIONS AND BENEFITS

The price of gasoline was an insignificant independent variable prior to 1973, and consumers may have over-reacted to it in that year. Therefore, the new car registrations equation may now place undue emphasis on this variable. The market shares equations are not constrained to sum to 100%, but rather are normalized to achieve that result.

STRUCTURE

This econometric model consists of a single equation which predicts the total new passenger car registrations annually and five equations which predict the market share for five size-classes of cars. The total new car registrations equation, which is reproduced below, was estimated by ordinary least squares using quarterly data from 1957 to 1973.

$$\begin{aligned} NCPR = 18.63 &+ \underset{(4.5)}{.0211} \sum_{i=0}^{4} (.6)^i \left(DI - \frac{TR}{PCI}\right)_{-i} \\ &- \underset{(-2.7)}{7.86} \left(\frac{PNC}{PCI}\right) - \underset{(-4.6)}{.37} (UN) + \underset{(6.8)}{.90} (DASTR) \\ &- \underset{(-2.8)}{.058} \sum_{i=0}^{4} (.6)^i (KNCR)_{-i} - \underset{(-2.3)}{7.00} \left(\frac{PCIGO}{PCI}\right) \end{aligned}$$

$$- \underset{(-2.8)}{.36} \frac{1}{4} \sum_{i=0}^{4} (CRED)_{-i} + \underset{(2.3)}{.46} (DDITC)$$

$\bar{R}^2 = .96$ DW = 1.52

where t-statistics are in parentheses, and

NCPR = new passenger car registrations, millions, seasonally adjusted at annual rates

DI = personal disposable income, billions of 1958 dollars, seasonally adjusted at annual rates

TR = transfer payments to persons, billions of current dollars, seasonally adjusted at annual rates

PCI = consumer price index, 1958 = 1.0

PNC = consumer price index for new cars, 1958 = 1.0

UN = rate of unemployment, %

DASTR = dummy variable for auto strikes in 1964, 1967, 1970

KNCR = stock of new cars on a new car equivalent basis,

$$KNCR = \sum_{i=0}^{40} (.953)^{i} (NCPR)_{-i}$$

PCIGO = consumer price index for gas and oil, 1958 = 1.0

CRED = Chase index of credit rationing

DDITC = dummy variable for cancellation and reinstatement of investment tax credit

Market-shares equations are then estimated for new car sales, classified as subcompact, compact, intermediate, standard, and luxury. The equation for intermediate cars, estimated using ordinary least squares for annual data from 1958 to 1972, is reproduced below.

$$PCT_{IM} = -1.56 + \underset{(2.7)}{.443} \left(\frac{MPG_{IM}}{MPG_{SC}}\right) - \underset{(-4.5)}{.70} \left(\frac{P_{IM}}{P_{ST}}\right)$$

$$+ \underset{(6.6)}{1.87} \left(\frac{PCIGO}{PCI}\right) + \underset{(8.0)}{.031} (T)$$

$\bar{R}^2 = .89$ DW = 2.24

where t-statistics are in parentheses, and

$PCT_{XX}$ = percent of total new car sales in the subclass XX

$MPG_{XX}$ = miles per gallon for a particular subclass

$P_{XX}$ = average price of a new car in a particular subclass

T = time trend

The remaining variable definitions appear above following the new car registrations equation.

Other share equations incorporate the unemployment rate as an independent variable.

## MODEL CONSTRUCTION

To specify the model data for all variables from 1957 to 1973 are required. Some data are listed in the model report for the share equations. However, the remaining data must be obtained from Chase or assembled from some other source.

## DATA USED IN RUNNING MODEL

The model requires forecast values for all independent variables. These forecasts are taken from the Chase macroeconomic forecast, although alternative assumptions could be used. The forecast values are included in Appendix II of the model report.

## DOCUMENTATION

Chase Econometric Associates, Inc., The Effect of Tax and Regulatory Alternatives on Car Sales and Gasoline Consumption, prepared for Council on Environmental Quality under Contract No. EQC004, Final Report, May 1974. NTIS No. PB-234 622.

# GASOLINE CONSUMPTION MODEL

This gasoline consumption model was prepared in 1974 by Chase Econometric Associates, Inc. for the Council on Environmental Quality. It forecasts gasoline consumption annually through 1986 for six tax and regulatory alternatives. It has been superseded by a new model which is proprietary and not included in this inventory.

## SPONSOR

Council on Environmental Quality
722 Jackson Place, NW
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## AUTHOR

Chase Econometric Associates, Inc.
One Chase Manhattan Plaza
New York, N.Y. 10015

## MODEL TYPE

Fleet size, scrappage, vehicle miles traveled, fuel consumption

## OBJECTIVE OF MODEL

The model forecasts gasoline consumption annually through 1986 for six tax and regulatory alternatives.

## RELATIONSHIP TO OTHER MODELS

This submodel requires input from the New Passenger Car Sales and Market Shares submodel (74-002A), which was prepared by Chase Econometric Associates, Inc. as part of the same study. It is used in conjunction with the Chase macroeconomic model.

## ASSUMPTIONS

The model assumes that scrappage is based on a cubic time trend relationship, and that all cars of a single year survive at the same rate. The miles per gallon calculation assumes that, for the baseline case, 1973 mpg figures apply for all subsequent years, and that 1957 mpg figures apply for pre-1957 years.

## VALIDATION

The author reports that the cubic scrappage equation tracks the actual survival rate of cars quite closely. The 1969-73 scrappage equations are adjusted to conform more closely to actual data, since predicted stock exceeded actual stock. No other validation efforts are reported.

## LIMITATIONS AND BENEFITS

The scrappage rate is not influenced by any economic variables. The miles per gallon calculation is subject to a number of biases since there are no corrections made in the fuel economy rating for the model year and age of each model of car.

## STRUCTURE

This econometric model first computes the annual automobile stock in the aggregate and by model year. These figures are used as input for the calculation of total vehicle miles traveled per year. Data and assumptions on average mileage per gallon for each model year are then used to calculate annual average mileage per gallon for all cars on the road in each forecast year. The VMT and mileage forecasts are then combined to generate annual forecasts of gasoline consumption through 1986. The scrappage rate is computed for each model year from an equation of the following form:

$$\frac{R_{MY,t}}{R_{MY}} = \alpha\, e^{B(T)^3}$$

where:

$R_{MY,t}$ = registrations in year t for model year MY

$R_{MY}$ = total original registrations for model year MY

T = age of the model year car

$\alpha$, B = coefficients

This equation is estimated using annual car registration data from 1951 to 1972 for model years 1951 to 1968. Calculated values of $\alpha$ and B are listed in the study report.

Vehicle miles traveled are explained by a single equation estimated using ordinary least squares for the period 1956 to 1972.

$$TVM = 3416.1 + \underset{(9.2)}{78.5}\,(CAR) - \underset{(-2.5)}{3944.5}\left(\frac{PCIGO}{PCI}\right) + \underset{(2.3)}{5181.0}\,(\Delta PCI)$$

$$+ \underset{(2.1)}{784.1}\,(PUVNC_{-2}) + \underset{(2.2)}{8.81}\,(\Delta YW)$$

$\bar{R}^2 = .996$ DW = 1.29

where t-statistics are in parentheses and

TVM = vehicle miles traveled

CAR = total number of personal passenger vehicles registered as of July

PCIGO = consumer price index of gasoline and oil, 1967 = 100

PCI = consumer price index of all goods and services, 1967 = 100

PUVNC = average price of new cars

YW = wages and salaries

Gasoline consumption is computed from the following formula:

$$GAS_T = \sum_{MY=1951}^{T} \left(\frac{R_{MY,t}}{CAR_T}\right) \left(\frac{TVM_T}{MPG_{MY}}\right)$$

where:

$GAS_T$ = gasoline consumed by passenger vehicles in calendar year T

$MPG_{MY}$ = miles per gallon for model year MY

and the other variables are as previously defined.

## MODEL CONSTRUCTION

Passenger car registration data by model year as of July 1 are from the series prepared by R.L. Polk and Co. Vehicle miles traveled data are from the Federal Highway Administration for 1956 to 1972. Data for the other variables in the TVM equation must be collected for the period 1956 to 1972. Environmental Protection Agency surveillance program statistics on miles per gallon by model year are also required.

## DATA USED IN RUNNING MODEL

The model requires new car sales and market share forecasts from the sales and market shares submodel (74-002A). Forecasts for the independent variables in the TVM equation were obtained from the Chase macroeconomic baseline forecast. Miles per gallon and price effects for the six scenarios are obtained from a study by Hittman Associates.

## DOCUMENTATION

Chase Econometric Associates, Inc., The Effect of Tax and Regulatory Alternatives on Car Sales and Gas Consumption, prepared for the Council on Environmental Quality under Contract No. EQC004, Final Report, May 1974, NTIS No. PB-234 622.

Hittman Associates, Inc., A Study of Industry Response to Policy Measures Designed to Improve Automobile Fuel Economy.

# TECHNOLOGY MODEL OF THE EEA GASOLINE CONSUMPTION MODEL

The Technology Model of the EEA Gasoline Consumption Model, dated July 1975, was prepared by Energy and Environmental Analysis, Inc. (EEA) for the Federal Energy Administration. The model computes new car fuel economy, weight, and price by manufacturer and size class for a variety of future fuel efficiency, emmission, and safety standards. The model has been exercised for the Office of Technology Assessment in their study "Technology Assessment of Changes in the Use and Characteristics of the Automobile."

## SPONSOR

Federal Energy Administration
Office of Conservation and Environment
Office of Transportation Programs
Washington, D.C. 20461

## AUTHOR

Energy and Environmental Analysis, Inc.
1701 North Fort Myer Drive
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Arlington, Va. 22209

## MODEL TYPE

Fuel economy, weight, pricing

## OBJECTIVE OF MODEL

The objective of the model is to compute new car fuel economy, weight, and price using a baseline and various assumptions as to future efficiency, emissions, and safety standards.

## RELATIONSHIP TO OTHER MODELS

The new car characteristics from this submodel serve as a basis for predicting new car sales, distribution of sales by market class and other parameters in the other submodels of the EEA Gasoline Consumption Model, 75-003B and 75-003C.

## ASSUMPTIONS

The model assumes that each manufacturer maintains his 1974 percentage of car sales in each size class, although overall market position may change. The model also assumes certain calculated feasible non-engine improvements for each manufacturer. Percentage weight changes are assumed to equal the percentage fuel economy changes, multiplied by a sensitivity factor for each size class. Finally, the model assumes that engine-related fuel economy improvements can be calculated from four emissions scenarios and three mutually exclusive emission control systems.

## VALIDATION

No validation efforts are reported for the technology model. However, the overall model predicts actual gasoline consumption reasonably well through 1974.

## LIMITATIONS AND BENEFITS

The model currently does not incorporate a specific fuel economy standard, although it can be modified to include such a standard.

## STRUCTURE

This is an econometric model which computes new car fuel economy, weight, and price using a baseline and the most recent data on likely trends and industry capabilities. It incorporates five manufacturers (four domestic plus all foreign manufacturers) and six market classes (subcompact, compact, intermediate, standard, small luxury and large luxury). For each manufacturer and market class, sales-weighted harmonic averages of fuel economy, price, and weight are calculated for 1974. A fuel economy improvement schedule is then developed by manufacturer and market class. Engine-related improvements are projected for four emission scenarios using data from a recent EPA study. Annual projected cost, weight, and fuel economy changes are added to the 1974 baseline of each manufacturer. Finally, cost and fuel economy by class are calculated by salesweighting the economy and cost data using the 1974 sales distribution data.

## MODEL CONSTRUCTION

The construction of this model requires 1974 sales, fuel economy, price, and weight data by automobile model. Alternative fuel economy improvement schedules are also required. Some of the data are included in the model report, and some are included in the accompanying computer program users' manual.

## DATA USED IN RUNNING MODEL

The model requires a choice among the fuel economy, safety standard, and emission scenarios built into the model. Alternatively, specific assumptions as to price, fuel economy, etc. can be incorporated by altering the data file.

## DOCUMENTATION

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. I, prepared for the Federal Energy Administration, Final Report, July 22, 1975.

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. II: Users Manual, prepared for the Federal Energy Administration, Final Report, September 1975.

Tradeoffs Associated with Possible Auto Emission Standards, Report to EPA prepared by Mobile Source Pollution Control Program, February 1975.

## COMPUTER REQUIREMENTS

The model is programmed in the FORTRAN IV G language. It is accessible from a time-sharing computer terminal. An illegible printout of the model appears in the user's manual.

75-003B

# ECONOMICS SUBMODEL OF THE EEA GASOLINE CONSUMPTION MODEL

The Economics Submodel of the EEA Gasoline Consumption Model, dated July 1975, was prepared by Energy and Environmental Analysis, Inc. (EEA) for the Federal Energy Administration. It provides medium-(3-5 years) and long-term (through 1990) projections of gasoline consumption by passenger cars for alternative fuel economy, emissions and safety standards. The model has been exercised for the Office of Technology Assessment in their study "Technology Assessment of Changes in the Use and Characteristics of the Automobile."

## SPONSOR

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## MODEL TYPE

Automobile demand, market share, vehicle miles traveled, fuel consumption

## OBJECTIVE OF MODEL

The model provides medium- (3-5 years) and long-term (through 1990) projections of gasoline consumption by passenger cars for alternative fuel economy, emissions, and safety standards.

## RELATIONSHIP TO OTHER MODELS

This submodel of the EEA Gasoline Consumption Model requires input from the technology submodel (75-003A) and provides output for use in the emissions submodel (75-003C).

## ASSUMPTIONS

The model assumes the average vehicle price to include the average cost of options actually purchased. The preliminary estimate of gasoline demand assumes that scrappage rate and vehicle miles of travel/ car rates remain constant over time and are the same for every class of car.

## VALIDATION

The author notes that the equations generally fit historical data well. Predictions for 1974 are generally within 1% of actual values. The preliminary estimate of gasoline demand, however, consistently understates actual demand by thirteen to sixteen percent.

## LIMITATIONS AND BENEFITS

The model measures the effect on gasoline consumption of changes in the pattern of usage of the existing fleet of vehicles.

## STRUCTURE

This model of gasoline consumption contains four sections: (1) share of new car sales by class of vehicle, (2) vehicle miles of travel, (3) new car sales, and (4) modifications to vehicle population and pricing patterns. First, six "economic" car classes are specified by combining wheelbase and price data. Average price per vehicle class is calculated from the formula:

$$P = BP + \sum_i (P_i)\ (O_i)$$

where:

$P$ = price of the model

$BP$ = base price of the model

$P_i$ = price of option i

$O_i$ = percentage of models sold with option i

For each class of car a market share equation is estimated from 1960 to 1974. Independent varibles tested in these equations include cyclical economic variables, new car price, fuel efficiency, and gasoline price. The share equation for sub-compacts is:

$$SCS = \underset{(-4.4)}{-.26} + \underset{(4.8)}{.0009}\ (\Delta YD/HH) - \underset{(-4.0)}{7.3}\ (\Delta YD/YD) + \underset{(5.6)}{.024}\ (U)$$

$$+ \underset{(2.1)}{.024}\ \left[\frac{P(GAS)}{MPG(SUB)}\right] + \underset{(3.1)}{.00096}\ \left[\frac{MPG(SUB)}{MPG(COM)}\right]\ [P(GAS)]$$

$$\bar{R}^2 = .95$$

where t-statistics are in parentheses, and

SCS = sub-compact market share

YD = real disposable income

HH = number of households

U = unemployment rate

P(GAS) = price of gasoline per gallon

MPG(SUB) = mileage per gallon for the sub-compact class

MPG(COM) = mileage per gallon for the compact class

The share equations are estimated without constraints, but then are normalized to sum to one for each year.

VMT is estimated from the following equation:

$$\frac{VMT}{HH} = \underset{(1.3)}{1.21} + \underset{(4.4)}{.21}\,(U) + \underset{(30.2)}{.0016}\left(\frac{YD}{HH}\right) - \underset{(2.2)}{25.6}\left[\frac{P(GAS)}{(CPI)(MPG)}\right]$$

$\bar{R}^2 = .99$

where t-statistics are in parentheses, and

VMT = vehicle miles traveled

CPI = consumer price index

and the other variables are as previously defined.

New car sales are determined from the equation:

$$NCS = \underset{(18.5)}{24.5} + \underset{(5.3)}{.036}\,(\Delta VMT) - \underset{(.7)}{1.36}\left[\frac{P(NC)}{CPI}\right] - \underset{(5.9)}{14.6}\left[\frac{P(NC)}{P(UC)}\right] + \underset{(2.6)}{1.98}\,(\Delta VMT/STOCK) - \underset{(2.9)}{.89}\,(STRIKE)$$

$\bar{R}^2 = .94$

where t-statistics are in parentheses, and

NCS = new car sales

P(NC) = new car price

P(UC) = used car price

ΔVMT/STOCK = actual VMT/STOCK for the previous year minus estimated (or "trend") VMT/STOCK

STRIKE = dummy variable for strike years

and other variables are as previously defined.

Finally a "preliminary" estimate of gasoline consumption is obtained for given levels of scrappage and VMT per car by age. The essential relationship is

$$V_{ij} = A_{ij}\ SA(k)\ SV(k)$$

where:

$V_{ij}$ = relative VMT for year i and class j

$A_{ij}$ = number of cars purchased in year i of class j

SA(k) = vehicle scrappage factor for cars k years old

SV(k) = relative VMT per car by age normalized by dividing by VMT/car in the current year.

This preliminary estimate is adjusted by the following equation:

$$\begin{aligned} AGD = \underset{(7.8)}{28.5} - \underset{(2.5)}{118}\left[\frac{P(GAS)}{CPI \times MPG(STOCK)}\right] - \underset{(2.0)}{.4}\,(U) \\ - \underset{(2.4)}{19.6}\left(\frac{\Delta YD}{YD}\right) - \underset{(5.9)}{10.5}\left[\frac{P(NC)}{P(UC)}\right] + \underset{(3.6)}{3.0}\,(\Delta VMT/STOCK) \\ + 1.0\ (\text{Estimated Gasoline Demand}) \end{aligned}$$

$\bar{R}^2 = .86$ DW = 2.0

where t-statistics are in parentheses,

AGD = actual gasoline demand,

and the other variables are as previously defined.

## MODEL CONSTRUCTION

The calibration of this model requires annual data from 1960 to 1974 for all variables. These data are not included in the model report.

## DATA USED IN RUNNING MODEL

Projections of all independent variables and of government regulations are required. The users' manual lists all necessary data in Appendix D.

DOCUMENTATION

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. I, Final Report, prepared for the Federal Energy Administration, July 22, 1975.

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. II: Users Manual, Final Report, prepared for the Federal Energy Administration, September 1975.

COMPUTER REQUIREMENTS

The program, written in FORTRAN IV G, operates interactively in time-sharing mode. The program requires 57,200 bytes of storage.

# EMISSIONS SUBMODEL OF THE EEA GASOLINE CONSUMPTION MODEL

The Emissions Submodel of the EEA Gasoline Consumption Model, dated July 1975, was prepared by Energy and Environmental Analysis, Inc. (EEA) for the Federal Energy Administration. The model uses total vehicle miles of travel (VMT) predictions, characteristics of the automobile population, and emission factors to predict nationwide total automotive exhaust emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides ($NO_x$). It has been exercised for the Office of Technology Assessment in their study "Technology Assessment of Changes in the Use and Characteristics of the Automobile."

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## MODEL TYPE

Emissions

## OBJECTIVE OF MODEL

The model uses total VMT predictions, characteristics of the automobile population, and emission factors to predict nationwide total automotive exhaust emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides ($NO_x$).

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the EEA Gasoline Consumption Model, which includes the Technology Submodel (75-003A) and the Economics Submodel (75-003B).

## ASSUMPTIONS

The model assumes that future emissions factors for all automobiles were accurately calculated by the Environmental Protection Agency. The amount of use for an individual car is assumed to be a function of only the age of the car, with older cars traveling less. Historic data on use by age is assumed to apply in the future.

## VALIDATION

Although no specific validation efforts are reported for the Emissions Submodel, the overall model predicts gasoline consumption reasonably well from 1960 to 1974.

## LIMITATIONS AND BENEFITS

The forecasts of the model are at best only as reliable as the VMT projections obtained from the Economics Submodel. The model currently incorporates only four emission standard scenarios.

## STRUCTURE

The model computes total automobile emissions based on projected VMT and the appropriate emissions rates, expressed as volume of emissions per mile traveled. Emissions rates for all vehicles through the 1976 model year are obtained from existing test data and from the preliminary edition of Supplement No. 5 for Compilation of Air Pollutant Emission Factors, EPA, April 15, 1975. The emission rates for vehicles manufactured after 1976 are determined by the selection of one of four different emission standard scenarios. Each standard implies a corresponding emission schedule by age of vehicle.

The model computes the percentage of total travel for each vehicle age group by multiplying historic data on travel for each vehicle age by the predicted number of cars in each age group on the road in a given year. Total vehicle miles traveled predicted in the Economics Submodel is distributed among cars on the road in each year according to these percentages. Emissions are calculated as miles traveled times the appropriate emission factor for each age group.

## MODEL CONSTRUCTION

The model requires emission factors by vehicle age for all vehicles on the road in a given year. These data are listed in Appendix C of the users' manual. Projections of total VMT and cars on the road in a given year are obtained from the Economics Submodel.

## DATA USED IN RUNNING MODEL

The model requires selection of one of four emission standards scenarios. Data describing these scenarios appear in Table VI-2 of the model report.

DOCUMENTATION

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. I, Final Report, prepared for the Federal Energy Administration, July 22, 1975.

Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Vol. II: Users Manual, Final Report, prepared for the Federal Energy Administration, September 1975.

COMPUTER REQUIREMENTS

The program, written in FORTRAN IV G, operates in an interactive time-sharing mode. It occupies 57,200 bytes of storage.

# AUTOMOBILE SIMULATION MODEL OF THE PROJECT INDEPENDENCE EVALUATION SYSTEM (PIES)

The Automobile Simulation Model was written in 1975 at the Federal Energy Administration (FEA) as part of the Project Independence Evaluation System (PIES). The purpose of the model is to examine the effects of several conservation policy options on gasoline consumption, new car sales, and total vehicle miles traveled. It has been used by the White House in the preparation of the National Energy Plan, by the Electric Power Research Institute for energy use forecasting, and by Washington State University in energy policy research.

## SPONSOR

Federal Energy Administration
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## AUTHOR

James Sweeney
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## MODEL TYPE

Vehicle miles traveled (VMT), automobile demand, fleet size, fuel economy, fuel consumption, vehicle user costs

## OBJECTIVE OF MODEL

The objective of the model is to forecast the impact on gasoline consumption, on new car sales, and on total vehicle miles traveled of several conservation policy options applicable to passenger cars. The options include efficiency standards, technical changes, gasoline taxes, and tariff options.

## RELATIONSHIP TO OTHER MODELS

The Automobile Simulation Model is one of three submodels of the Transportation Sector of the PIES energy demand model. Other submodels of the Transportation Sector are the Other Vehicles Model and the Natural Gas Transportation Model. Three other sectors (Household, Commercial, and Industrial) comprise the PIES energy demand model. Output from the FEA World Energy Model (75-004B) is used as input to PIES.

## ASSUMPTIONS

The model is based on the following assumptions:

1) average MPG for each car vintage remains unchanged;

2) consumers calculate a desired stock of automobiles and buy new cars in order to adjust the total stock of cars from its existing level to its desired level;

3) gasoline prices (before taxes) are not influenced by policy options;

4) refinery yield constraints will not act as a significant bottleneck retarding the realization of the reductions; and

5) sufficient policy instruments exist to implement efficiency standards.

## VALIDATION

The model has been run for the period 1975 to 1985 to test the impact of policy options on gasoline demand for passenger cars, vehicle miles of passenger cars, fuel efficiency of new cars, fuel efficiency of the fleet of cars, new automobile sales, and passenger car registrations. It was found that reductions in gasoline demand could be obtained by the use of efficiency standards, gasoline taxes, or tariffs. Gas taxes reduce demand through reductions in vehicle miles traveled and increased efficiency, in the short run.

## LIMITATIONS AND BENEFITS

The model results only indicate shifts in demand for gasoline, not supply.

## STRUCTURE

The econometric equations were developed from ordinary least squares techniques, except for vehicle miles traveled, which was developed using nonlinear least squares with first-order autoregressive transformation. The equations of the model are:

$$\begin{aligned} \text{VMAUTO} = N \times \exp[\ & \underset{(12.683)}{.80967}\ (\log[\text{VMAUTO}(-1)/N(-1)]) \\ & + \underset{(12.1275)}{6.5184} - \underset{(-1.785)}{.35775}\ (\log[\text{COSTPM}]) \\ & + \underset{(11.1515)}{.97561}\ (\log[\text{YD58\%N}]) + \underset{(0.9352)}{.0026184}\ (\text{RU}) \end{aligned}$$

$$- .80967\ (6.5184 - .35775\ [\log(COSTPM[-1])] + .97561\ [\log(YD58\%N[-1])] + .0026184\ [RU(-1)])]$$

$\bar{R}^2 = .9959$

where t-statistics are in parentheses, and

COSTPM = cost per mile of driving an automobile

VMAUTO = total vehicle miles of all passenger cars on the road (millions)

YD58%N = disposable income per person in 1958 dollars (thousands)

RU = unemployment rate as defined by the Bureau of Labor Statistics

N = total populations (millions)

$$NPCR = N \times \exp[\underset{(.6564)}{4.0792} - \underset{(-6.2754)}{3.7554}\ (\log[OMEGA(-1)/N(-1)]) + \underset{(2.4835)}{2.3155}\ (\log[VMAUTO/N]) + \underset{(1.9503)}{1.7780}\ (\log[YD58\%N]) - \underset{(-3.6297)}{.078164}\ (RU)]$$

$\bar{R}^2 = .8964$

NPCR = new passenger car sales (thousands)

OMEGA = age adjusted stock of automobiles

$$PCRAUTO = \underset{(629.97)}{.930943}\ [PCRAUTO(-1)] + NPCR$$

$\bar{R}^2 = .9991$

PCRAUTO = stock of automobiles (thousands)

OMEGA = NPCR + DELTA x B x OMEGA(-1)

DELTA = survival rate, the fraction of automobiles that survive from one year to the next, = .93

B = age adjustment factor, which adjusts for the fact that older cars are driven less, = .92

$$MPGAUTO = \exp[\underset{(31.8728)}{3.22175} + \underset{(7.5798)}{.68777}\ (\log[(PGAS[-1]/CPI[-1]) / EFF]) + (\log[EFF])]$$

$\bar{R}^2 = .8343$

CPI = consumer price index

PGAS = price of gasoline in nominal dollars per gallon, including taxes

MPGAUTO = miles per gallon of new cars

EFF = measure of technical efficiency

THETA = NPCR/MPGAUTO + DELTA x B x THETA(-1)

THETA = fuel use per mile driven, allows miles per gallon of new cars to affect the miles per gallon of the stock

AMPGAUTO = OMEGA/THETA

AMPGAUTO = average miles per gallon of the stock of automobiles on the road

COSTPM = (RIDERSPC x WGFAC x AHEEA/CPI) / (.5 [AVSPEED] + 10.0)

+ (PGAS/CPI)/AMPGAUTO

RIDERSPC = number of passengers per car (assumed to equal 1.3)

WGFAC = wage factor or the proportion of wages that people feel they lose while driving as opposed to work-related activities (assumed to equal 0.4)

AHEEA = per hour wage rate in nominal dollars

GASAUTO = VMAUTO/AMPGAUTO

GASAUTO = total gasoline consumption of all cars in gallons of gasoline (millions)

## MODEL CONSTRUCTION

Historical values of the independent variables were used in model estimation. Sources of these data were: the Federal Highway Administration, the Environmental Protection Agency, the "Nationwide Personal Transportation Study," the Motor Vehicle Manufacturers Association, the Department of Commerce, and the American Petroleum Institute.

## DATA USED IN RUNNING MODEL

Forecasts of the following variables are required to run the model:

1) total population (millions),

2) cost per mile of driving an auto,

3) total vehicle miles of all autos on road,

4) unemployment rate as defined by Bureau of Labor Statistics,

5) new passenger car sales,

6) age adjusted stock of automobiles,

7) stock of automobiles,

8) price of gasoline,

9) consumer price index,

10) assumed miles per gallon,

11) average miles per gallon of the auto stock,

12) number of passengers/auto,

13) loss of wages resulting from driving,

14) per-hour wage rate, and

15) average speed on road.

The macroeconomic variables used by the author in forecasting were derived from the Data Resources, Inc. macroeconomic model.

## DOCUMENTATION

Federal Energy Administration, Office of the Assistant Administrator for Policy and Analysis, Office of Energy Systems, Pasenger Car Use of Gasoline: An Analysis of Policy Options, February 7, 1975.

# WORLD ENERGY MODEL

The World Energy Model was written by the Federal Energy Administrtion (FEA) in 1975. Its purpose is to generate forecasts of world crude oil prices and the U.S. crude oil imports at different levels of prices. Output from this model is used by the FEA as input to the Project Independence Evaluation System (PIES) model with which it is compatible.

## SPONSOR

Federal Energy Administration
Washington, D.C. 20461

## AUTHOR

Federal Energy Administration
Washington, D.C. 20461

## MODEL TYPE

Energy consumption

## OBJECTIVE OF MODEL

The objective of the World Energy Model is to generate forecasts of world crude oil prices and U.S. crude oil imports at different price levels.

## RELATIONSHIP TO OTHER MODELS

Output from this model, as well as that from the Automobile Simulation Model (75-004A), is used as input to the PIES model.

## STRUCTURE

The FEA World Energy Model is an econometric linear programming representation of the various segments of the world energy market, including demand, refining, transportation, supply, flows and pricing processes. The structure and methodology of the model is highly compatible with PIES. The model has eight submodels: macroeconomic, econometric demand forecasting, refinery, energy transformation, transportation, supply, economic, and equilibrium.

## DOCUMENTATION

Ali Ezzati, "FEA World Energy Model," Federal Energy Administration, presented at the International Energy Analysis Seminar, June 9-10, 1975, Rosslyn, Virginia.

# MODIFIED ROLLBACK PROGRAM

The Modified Rollback Program was written by the Environmental Protection Agency (EPA) in 1974. Its purpose is to calculate either both projected air quality and air pollutant emissions, or pollutant emissions only.

## SPONSOR

Environmental Protection Agency
Research Triangle Park, N.C. 27711

## AUTHOR

Environmental Protection Agency
Air Management Technology Branch
Monitoring and Data Analysis Division
Office of Air Quality Planning and Standards
Research Triangle Park, N.C. 27711

## MODEL TYPE

Air pollution/air quality

## OBJECTIVE OF MODEL

The objective of the model is to calculate air quality and air pollutant emissions, or pollutant emissions only. It is a long-range model.

## RELATIONSHIP TO OTHER MODELS

The modified rollback model may be used in conjunction with an Environmental Protection Agency (EPA) health model. Output from the rollback model is used as input to the health model, which forecasts marginal increases in certain diseases due to increased levels of pollutants.

## HISTORICAL BACKGROUND

The Environmental Protection Agency was established in 1970 to ensure that the provisions of the Clean Air Act and its 1970 amendments were carried out. The rollback model is one tool the EPA uses in their work.

ASSUMPTIONS

The model assumes that if emission sources were reduced by a certain fraction, air quality will improve by that fraction.

VALIDATION

The model's projections are compared to observed air quality in the Los Angeles area for the years 1964 to 1974. In general the model predicted past air quality trends, which were similar to measured values. Its ability to predict in the future is judged to be better for relative trends than for actual projected values.

LIMITATIONS AND BENEFITS

The assumption about the proportionality of emissions and air quality may not hold true in all situations.

STRUCTURE

$$X_j = B + (X_o - B) \left(\sum_{i=1}^{n} Q_i G_{ij} F_{ij} K_i T_{ij}\right) / \left(\sum_{i=1}^{n} Q_i K_i\right)$$

where:

$X_j$ = projected air quality concentration for calendar year j

B = background concentration

$X_o$ = base year air quality concentration

$Q_i$ = base year emission inventory for source category i

$G_{ij}$ = growth factor for source category i in year j

$F_{ij}$ = emission factor ratio for source category i in year j

$K_i$ = emission height factor for source category i

$T_{ij}$ = transportation control factor, if applicable, for source category i in year j

n = number of source categories

i = source category index

j = calendar year index

## MODEL CONSTRUCTION

The model is a set of physical theoretical relationships.

## DATA USED IN RUNNING MODEL

The model user must choose and designate the areas for which an air quality projection is desired; designate the name, base year, and base year concentration of the pollutant for which an air quality projection is desired; choose as many as six mobile sources and six stationary source categories of the twenty-six available; and select base year emissions, compound growth rates, and compound retirement rates for each category chosen.

## DOCUMENTATION

E. Tuerk, Air Quality, Noise and Health, Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976.

Modified Rollback Computer Program, Documentation, Draft, Environmental Protection Agency, Air Management Technology Branch, Monitoring and Data Analysis Division, Office of Air Quality Planning and Standards, April 7, 1977. This document gives instructions for running the program and contains the program listing.

## COMPUTER REQUIREMENTS

The model is written in FORTRAN for a UNIVAC computer.

# HIGHWAY FUEL CONSUMPTION MODEL

The Highway Fuel Consumption Model was prepared in April 1974 by the Transportation Systems Center (TSC) for the U.S. Department of Transportation. The objective of the model is to provide an estimate of future vehicle population mixes by age of vehicle and fuel category, and to calculate the fuel consumption rate of such a vehicle distribution.

## SPONSOR

U.S. Department of Transportation
Office of the Assistant Secretary for Systems Development and Technology, and Office of the Assistant Secretary for Policy and International Affairs
Washington, D.C. 20590

## AUTHOR

H.H. Gould and A.C. Malliaris
U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## MODEL TYPE

Vehicle miles traveled, fuel consumption, fleet size

## OBJECTIVE OF MODEL

The objective of the model is to provide an estimate of future vehicle population mixes by age of vehicle and fuel category, and to calculate the fuel consumption rate of such a vehicle distribution.

## RELATIONSHIP TO OTHER MODELS

The model bears no direct relationship to other models.

## ASSUMPTIONS

The model assumes a standard decay rate as a function of age for all automobiles.

## VALIDATION

The model was tested for consistency of options in the computer program. Eleven scenario projections are presented in the report.

However, the report does not discuss any validation efforts.

## LIMITATIONS AND BENEFITS

The model does not forecast or predict gasoline consumption based on explanatory variables. It estimates, on the average, the sensitivity of total fuel consumption to changes in the fuel economies of new cars introduced into the vehicle population and the effects of the existing vehicle inventory. An accounting is made entirely from data supplied by the user.

## STRUCTURE

The model calculates fuel consumption over time given the user-specified values of:

1) the distribution of initial year vehicle population by fuel economy,

2) vehicle miles driven per year as a function of vehicle age,

3) survival rates of the vehicles as a function of age,

4) projected vehicle population (or vehicle miles) as a function of time, and

5) projected fractional mix, by fuel categories, of new cars added to the vehicle population during each projected year.

Given the data, the model calculates new car sales for each projected year by subtracting surviving vehicles from the total vehicle population. New car sales are distributed by fuel category, and fuel consumption is calculated from the formula:

$$F_{ij} = \sum_{k=2}^{k_{max}} N_{ijk} C_j M_{ik} + N_{ij1} C_j M_{i1}$$

where:

i = year

j = fuel consumption category

k = age of vehicle

F = fuel consumption

N = number of vehicles

C = fuel consumption, gal/mile

M = miles driven per year

MODEL CONSTRUCTION

This model is a set of physical theoretical relationships.

DATA USED IN RUNNING MODEL

The model requires initial year data for all variables, and projections of all the input variables for each forecast year. The data values for several scenarios are listed in the model report.

DOCUMENTATION

Gould, H.H. and A.C. Malliaris, Highway Fuel Consumption Computer Model (Version I), Final Report, Department of Transportation, Report No. DOT-TSC-OST-73-43, April 1974.

Theodore M. Barnhill, "DOT Highway Fuel Consumption Model" (Version I as revised), Motor Vehicle Manufacturers Association, 1975.

COMPUTER REQUIREMENTS

The model is programmed in FORTRAN. A program listing is included in the model report.

# AUTO FLEET SUBMODEL

The Auto Fleet Submodel, dated February 1976, is a computer program used by the Transportation Systems Center (TSC) to implement the consumer sector of its modeling effort for the Task Force on Motor-Vehicle Goals Beyond 1980. It was prepared for TSC by Kentron Hawaii, Ltd. The model provides forecasts of fleet characteristics, emissions, mileage, and fuel data for three size-classes of cars and up to five "families" of structural specifications.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Data Services Division
Systems Application and Programming Branch
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

Alexander F. Robb
Scientific Applications Programming Section
Kentron Hawaii, Ltd.
Cambridge, Mass. 02142

## MODEL TYPE

Automobile demand, market share, vehicle miles traveled (VMT), scrappage, emissions, fuel economy

## OBJECTIVE OF MODEL

The Auto Fleet Submodel is designed to provide forecasts of fleet characteristics, emissions, mileage, and fuel data for three size-classes of cars and up to five "families" of structural specifications.

## RELATIONSHIP TO OTHER MODELS

This model constitutes the consumer submodel of a larger modeling effort by TSC. The model receives inputs from other submodels which predict resource requirements and automobile production. It provides outputs to the auto design evaluation submodel and the environmental impact assessment submodel. In particular, the fleet model is used as input to ARAM (76-024A).

ASSUMPTIONS

The model assumes that up to five families of cars will exist at any one time. Families are defined by engine, transmission, and structural specifications, and by whether certain levels of emissions and safety standards are met.

VALIDATION

The model report does not describe any validation of the model.

STRUCTURE

The model forecasts fleet size, VMT, new car sales, fuel consumption, and emissions for a specified number of years. The model report does not describe the actual structure of the model.

MODEL CONSTRUCTION

The model requires the following data base:

1) data for the initial fleet (1975) by age, class, and family,

2) miles driven by age of car,

3) scrappage rate by age of car,

4) type of fuel used,

5) fuel efficiency by year, class, and family,

6) vehicle weight,

7) crashworthiness,

8) emission rates for three pollutants for each family,

9) new car price by year, class, and family,

10) emission category by family.

Data values used in the model are listed in Appendix A, pp. A-34 to A-36, and Appendix D, p. D-1 of the model report.

DATA USED IN RUNNING MODEL

For each year of the forecast the model requires input values for the unemployment rate, new car mix by class, sales mix by family, and descriptive data for each new family of cars. Total sales, total VMT, and total vehicle population can be input, or they can be forecast using quarterly input values for population over the age of 16, price of new cars, total population, unemployment rate, Moody's AAA interest rate, and historical new car sales from 1965 to 1974. Annual values are required for the number of drivers, real disposable income, number of households, and real price of gasoline. Data values used are listed in the model report in Appendix D, pp. D-2 to D-5.

## DOCUMENTATION

Alexander F. Robb, Auto Fleet Submodel, Final Report, prepared by Kentron Hawaii, Ltd. for TSC/DOT under contract No. DOT/TSC-1146, February 23, 1976.

A.F. Robb, Update of User's Manual for the Fuel Forecast Program, External Memo KH10-F29200 - EM 581/75, November 14, 1975.

## COMPUTER REQUIREMENTS

The model is programmed in FORTRAN IV (F40). A copy of the program is included in the model report.

73-010

# A USER COST APPROACH TO NEW AUTOMOBILE PURCHASES

A User Cost Approach to New Automobile Purchases, dated January, 1973, was developed at Pomona College under a grant from the Ford Foundation. The objectives of the research were to investigate a superior goods approach to modeling new car purchases and to compare this approach with the commonly used "stock-adjustment" approach.

## SPONSOR

Ford Foundation
Grant Allocated by Pomona College Research Committee

## AUTHOR

Frank C. Wykoff
Pomona College
Claremont, California

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objectives of this research are to examine a superior goods approach to modeling new car purchases and to compare this approach with the commonly used "stock-adjustment" approach. The hypothesis is tested that new cars are viewed by consumers as superior to used cars.

## RELATIONSHIP TO OTHER MODELS

This model has no direct relationship to other models.

## HISTORICAL BACKGROUND

There has been much econometric work investigating the user-cost element in corporate investment decisions. There are parallels between investment decisions by firms and durable purchase decisions by consumers, yet user-cost theory has not been applied to consumer goods.

## ASSUMPTIONS

The following assumptions were made in the construction of the model:

1) Utility to the consumer is derived from the services of durable goods, and it is the price of the services, not the purchase

price, that determines the demand (the user-cost-of-capital theory).

2) The rental price of a car for a year is the opportunity cost of holding the car plus the loss of value of the car over the year.

3) New-car services are "superior goods" relative to used-car services.

4) Private transportation is a necessity.

5) Used cars will influence new-car demand through their implicit rental prices as inferior substitutes.

6) Used cars are not perfect substitutes for new cars but are perfect substitutes for other used cars.

VALIDATION

There are no validation procedures discussed in the article on the model. The data, however, appear to fit the model well. From the test results of the user cost and superior goods hypothesis several observations are possible:

1) New and used cars are not perfect substitutes and, therefore, purchases of the former cannot be treated as simple additions to existing stock of cars.

2) Price and income elasticities, goodness-of-fit comparisons of competing models, and depreciation patterns suggest new car services are qualitatively superior to those of used cars.

3) New car purchases are price inelastic when a user-cost approach is used to estimate automobile demand from rental prices.

4) New-car income elasticities are around one, indicating new cars are normal, not luxury goods.

5) Using the oversimplified stock-adjustment approach, sixty to eighty percent of new demand results in current-period purchases, indicating a lag adjustment should be made for this approach.

6) Rental prices compare favorably to purchase prices.

7) Rental price coefficients are smaller than those of purchase prices but also have smaller standard errors.

8) Rental price elasticities are smaller, and the estimates more precise, than those of purchase prices.

## LIMITATIONS AND BENEFITS

It appears that behavior in the used car market cannot be explained totally as a residual from new car purchase decisions of the past.

## STRUCTURE

The superior goods model is represented by two equations:

A = A(I,C,U)

where:

A = demand for new car purchases

I = consumers' income constraint

C = user cost of a new car

U = user cost of a used car

U = U(I,C,S)

where:

U = demand for used cars

I = consumers' income constraint

C = user cost of new car rentals

S = existing stock of cars

The equations were studied using a variety of functional forms: aggregate-linear, per-family-linear, and log-linear. Results were invariant over these forms.

## MODEL CONSTRUCTION

Data including disposable income, number of families in U.S., total expenditures, consumer price index, and four to six month prime commercial paper rate were obtained from Survey of Current Business, Current Population Reports and the Federal Reserve Bulletin. Stock and new-purchase data by make and model year were obtained from R.L. Polk and Co., while new and used purchase prices by make and age were obtained from the Kelly Blue Book.

DOCUMENTATION

Frank C. Wykoff, "A User Cost Approach to New Automobile Purchases," _Review of Economic Studies_, Volume 40, July 1973.

# A METHOD FOR PROJECTING AGGREGATE AUTO MILES TRAVELED

A Method for Projecting Aggregate Auto Miles Traveled was prepared at the U.S. Department of Transportation (DOT), Transportation Systems Center (TSC) in 1975. It provides forecasts of vehicle miles traveled (VMT) that are sensitive to the price of gasoline and auto fuel economy.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

Donald E. Ward and Linda Horan
U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## MODEL TYPE

Vehicle miles traveled

## OBJECTIVE OF MODEL

The objective of the model is to forecast VMT in a model that is sensitive to the price of gasoline and auto fuel economy.

## RELATIONSHIP TO OTHER MODELS

The model has been used in conjunction with the model presented in Robert Mellman, "An Econometric Model of New Car Sales," TSC/DOT, Cambridge, Mass., October 1975 (75-013).

## HISTORICAL BACKGROUND

The model was developed by TSC to provide forecasts of VMT until a more comprehensive model became available.

## ASSUMPTIONS

The model assumes that a stock adjustment mechanism determines VMT.

## VALIDATION

The model tracks annual VMT reasonably well from 1954 to 1974, with an $R^2$ of .99.

## LIMITATIONS AND BENEFITS

The model has been superseded by the Environmental Impact Center's (EIC) VMT model (76-022A) and others.

## STRUCTURE

The model consists of a single equation that is estimated by ordinary least squares with annual data from 1951 to 1974.

$$V(t) = \underset{(1.06)}{1590} + \underset{(6.21)}{.6233}\,[V(t-1)] + \underset{(2.07)}{2153}\,(D) + \underset{(2.57)}{.3936}\,(R) - \underset{(-5.75)}{140580}\,\left(\frac{P}{E}\right)$$

$$R^2 = .99$$

where t-statistics are in parentheses, and

V(t) = vehicle miles traveled per household in year t

D = number of drivers per household

R = real disposable income per household (1958 dollars)

P = real price of gasoline (1967 dollars)

E = average fleet fuel efficiency (miles per gallon)

## MODEL CONSTRUCTION

This model was calibrated using annual values for the independent variables from 1954 to 1974. The sources are not indicated in the report of the model.

## DATA USED IN RUNNING MODEL

Assumptions are necessary for the future values of real disposable income per household, real price of gasoline, new car sales, and new car fuel economy. Representative assumptions are included in the model report.

DOCUMENTATION

D.E. Ward and L. Horan, _A Method for Projecting Aggregate Auto Miles Traveled_, Working Paper, TSC/DOT, WP-230-U.2-78, May 1975.

# AN ECONOMETRIC MODEL OF NEW CAR SALES

An Econometric Model of New Car Sales, dated October 1975, was prepared at the Transportation Systems Center (TSC). The model was designed to be sensitive to macroeconomic conditions and to purchase price and fuel costs of automobiles.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

Robert Mellman
U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142
(Robert Mellman is now with Charles River Associates, Cambridge, Mass.)

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to estimate the demand for new automobiles as a function of macroeconomic conditions and the purchase price and fuel costs of automobiles.

## RELATIONSHIP TO OTHER MODELS

Input includes forecasts of the effect of user costs on vehicle miles traveled from Donald Ward and Linda Horan, A Method for Projecting Aggregate Auto Miles Traveled, Working Paper, TSC/DOT WP-230-U.2-78, May 1975 (75-011).

## HISTORICAL BACKGROUND

The report was prepared under PPA No. OS 514, Requirements Analysis Subproject of Automobile Energy Efficiency Program sponsored by the Office of the Assistant Secretary for Systems Development and Technology, TST, U.S. DOT.

ASSUMPTIONS

User costs such as gasoline price and tax rate enter the model only indirectly through their impact on vehicle miles traveled. The stock of cars variable assumes a constant depreciation rate.

VALIDATION

All coefficients have the proper signs, and all but one are significant at the 95% level. The equation tracks actual car sales quite well from 1958 to 1975, with an $R^2$ of .88.

LIMITATIONS AND BENEFITS

The structure of the equation is due in large part to multicollinearity among several of the independent variables.

STRUCTURE

The equation is estimated using ordinary least squares for quarterly data from 1958 II to 1974 III.

$$\log\left(\frac{Q}{N16}\right) = \underset{(9.15)}{17.90} - \underset{(2.42)}{1.69}\left[\log\left(\frac{P}{YD}\right)\right] + \underset{(1.36)}{1.01}\left[\log\left(\frac{P}{YD}\right)_{-1}\right]$$

$$- \underset{(5.52)}{.41}\left[\log(u)\right] - \underset{(3.85)}{.50}\left[\log(r)\right] - \underset{(2.81)}{.46}\left[\log\left(\frac{P}{Pu}\right)\right]$$

$$+ \underset{(5.71)}{2.34}\left[\log\left(\frac{VMT}{STOCK}\right)_{-1}\right] + \underset{(3.62)}{.12}\,(STRIKE) + \underset{(6.93)}{.12}\,(DSA)$$

where t-statistics are in parentheses and

Q = quarterly sales of new cars

N16 = population over 16 years

YD = disposable income per capita, 1958 dollars

P = index of real new car price

u = national unemployment rate

r = Moody's AAA bond interest rate

Pu = index of real used car price

VMT = auto miles traveled per quarter

STOCK = stock of cars

DSA = seasonal adjustment dummy variable

STRIKE = auto industry strike dummy variable

## MODEL CONSTRUCTION

This model was calibrated using quarterly data for all of the variables from 1958-II to 1974-III. The values of new car sales, income, unemployment, and the interest rate were obtained from Survey of Current Business. Vehicle miles traveled was taken from Highway Statistics, by The Federal Highway Administration. Population over sixteen years old was from the U.S. Bureau of the Census. New and used car prices were from the Bureau of Labor Statistics consumer price indices.

## DATA USED IN RUNNING MODEL

The model requires forecasts of real car and real gasoline prices, of real disposable income, of gasoline taxes, and of average fuel efficiency.

## DOCUMENTATION

R. Mellman, An Econometric Model of New Car Sales, TSC, Report No. WP-210-U2-111, October 1975.

Donald Ward and Linda Horan, A Method for Projecting Aggregate Auto Miles Traveled, TSC Working Paper WP-230-U.2-78, May 1975 (75-011), subject to change.

# AUTOMOBILE SECTOR FORECASTING MODEL

The Automobile Sector Forecasting Model, commonly referred to as the Faucett Model, was written in 1976 by Jack Faucett Associates, Inc. under the sponsorship of the Federal Energy Administration. Its objective is to model the effects of alternate fuel economy policies on future gasoline consumption, vehicle miles traveled, new car sales, fleet size, fleet composition, stock of cars, new car prices, and fuel economy. It has been used by the Federal Energy Administration, the Energy Research and Development Administration, the White House, The Transportation Systems Center, by the Congressional Budget Office for evaluating the President's National Energy Plan, and by the National Highway Traffic Safety Administration (NHTSA) for studying the effects of passive restraints.

## SPONSOR

Federal Energy Administration
Washington, D.C. 20461

## AUTHOR

Jack Faucett Associates, Inc.
5454 Wisconsin Avenue
Chevy Chase, Md. 20015

## MODEL TYPE

Automobile demand, vehicle miles traveled, scrappage, market shares, fuel consumption

## OBJECTIVE OF MODEL

The objective of the model is to estimate the effects of alternative fuel economy policies on future gasoline consumption, vehicle miles traveled, new car sales, fleet size, fleet composition, stock of cars in use, new car prices, and fuel economy.

## RELATIONSHIP TO OTHER MODELS

This model has no relationship to other models.

## HISTORICAL BACKGROUND

The model was prepared for use in the Motor Vehicle Goals Beyond 1980 Study.

## ASSUMPTIONS

The fundamental concept used to specify the model of new car sales is that of a short-run stock adjustment approach. In such a model, new car sales is assumed to be related to the gap between a "target" stock of automobiles at the beginning of the current period less those cars that will be scrapped during the year. The target automobile ownership is assumed to be positively related to household income. In addition, the rate at which automobile ownership per household increases decreases with rising income per household. To calculate the target ownership, the authors of the model observe that automobile ownership by income group is relatively stable over time and thus they assume that the relationship between target ownership and household income can be estimated cross-sectionally with 1970 data.

## VALIDATION

The model has been run using twenty-one alternative input scenarios through the year 2000. All of the scenarios predict a fall in fuel consumption through 1985 and varying increases through 2000. Each scenario predicts a rise in VMT at varying rates. Increases and decreases in auto stock are predicted by different scenarios. Fuel economy standards are judged to be the best way of conserving fuel with fewer negative side effects.

## LIMITATIONS AND BENEFITS

The alternative fuel economy policies that can be tested by the model are new car excise taxes and rebates, fuel economy standards, and influences on the price of gasoline.

## STRUCTURE

The Faucett model is made up of two major components: an automobile industry simulation component and an automobile demand and travel forecasting component.

The automobile industry simulation component determines fuel economies and prices of three size classes of cars: small, mid-size, and large. These fuel economies and prices are calculated through a complex procedure which attempts to minimize: (1) the cost of a car to the consumer, (2) the cost of automobile travel to the consumer (this is inversely proportional to fuel economy), (3) the taxes to the consumer that may result under a tax/rebate program which is based on the fuel economy of cars, and (4) the civil penalties to the industry that can occur as a result of the fuel economy standards.

The demand and travel forecasting component determines the result of the price and fuel economy decisions on new car sales, travel demand, and gasoline consumption. This component of the model is based essentially on a stock-adjustment approach, and it is composed of several interrelated submodels including those for surviving cars on the road, generalized price, target auto ownership, new car sales, market shares, vehicle miles traveled, petroleum product consumption, vehicle price, and fuel economy. The model equations are as follows:

$$N_t = 286{,}721.3\,(O^*_t - \text{Autos}_t - D_t)^{.2178}\,(X^*_t)^{-1.7039}$$

$$O^*_t = (\sum_I H_I\,P_{It})\,\text{HHLD}_t$$

$$H_I = (.017861)^{.4743}$$

$$S_t = 1/(1 + e^{-[-4.1749 - 1.8660\,(X^S_t) + 3.5093\,(X^M_t) + 5.6428\,(S_{t-1})]})$$

$$M_t = 1/(1 + e^{-[-4.1749 - 2.0765\,(X^M_t) + 3.5450\,(X^S_t) + .2589\,(X^L_t) + 5.6428\,(M_{t-1})]})$$

$$L_t = 1/(1 + e^{-[-4.1749 - .4299\,(X^L_t) + 1.8117\,(X^M_t) + 5.6428\,(L_{t-1})]})$$

$$\text{SPG}_t = .4068 - .0784\,(P_n)_t - .0155\,(U_t)$$

$$\frac{\text{VMT}}{\text{HHLD}_t} = -52979.8 + 15087\,[\log(\frac{\text{DI}}{\text{HHLD}_t})] - 2204.24\,(\text{CMP})_t + 6337.24\,(\frac{\text{Autos}}{\text{HHLD}_t})$$

where:

$N_t$ = total new car sales in year t

$O^*_t$ = target ownership of automobiles in year t

$(\text{Autos})_t$ = the stock of automobiles on hand as of January 1 of year t

$H_I$ = the number of cars per household for income group I

$D_t$ = the number of autos scrapped during year t

$X^*_t$ = an index of the real generalized price of new cars, 1967 = 1.00

$S_t$, $M_t$, $L_t$ = market shares of small, medium, and large cars, respectively, in year t

$X^S_t$, $X^M_t$, $X^L_t$ = an index of the real generalized price of small, medium, and large cars, respectively, relative to that of all new cars in year t, 1967 = 1.00

$SPG_t$ = the rate of scrappage in year t of vehicles eight or more years of age.

$(P_n)_t$ = an index of the real price of new cars in year t, 1967 = 1.00

$U_t$ = the unemployment rate in year t

$DI_t$ = total real disposable income in year t

$VMT_t$ = total vehicle miles traveled in year t

$CPM_t$ = an index of the fleet real gasoline costs per miles in year t, 1967 = 1.00

$HHLD_t$ = the total number of households existing in year t

$P_{It}$ = fraction of total households in year t having income I

For each year, 1976-2000, the model outputs the following:

1) new car sales,
2) new car sales by size class,
3) average fuel economy by new car fleet,
4) fuel economy by class,
5) new car prices,
6) new car prices by class,
7) number of cars in operation,
8) cars in operation by size class,
9) cars scrapped during year,
10) gasoline price,
11) vehicle miles traveled,
12) total gasoline consumed, and

13) size class weighted average generalized price.

## MODEL CONSTRUCTION

Data used to build the model were based on at least these sources:

1) Survey of Consumer Finances, Survey Research Center, The University of Michigan

2) Nationwide Personal Transportation Study, Federal Highway Administration

3) Current Population Reports, U.S. Bureau of the Census

4) Highway Statistics, Federal Highway Administration

5) Census of Population, U.S. Bureau of the Census

6) National Survey of October New Car Buyers, Rogers National Research

## DATA USED IN RUNNING MODEL

Data for these variables are required: gasoline prices and new car fuel economy policies (excise tax/rebate description, and fuel economy standards/penalties).

## DOCUMENTATION

Jack Faucett Associates, Inc., Automobile Sector Forecasting Model Documentation, submitted to the Federal Energy Administration, Final Report, JACKFAU-76-137-7, August 1976.

Jack Faucett Associates, Inc., Fuel Economy Policies and Their Effects on Automobile Ownership, Use, and Fuel Consumption, submitted to the Federal Energy Administration, Final Report, JACKFAU-76-137-7, August 1976.

C. Difiglio and D. Kulash, Marketing and Mobility: Report of a panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, Interim Report, March 1976.

## COMPUTER REQUIREMENTS

The model is written in FORTRAN and is operational on the IBM 370. The programs are written for interactive use by a user at a remote terminal.

# GENERAL PURPOSE AUTOMOTIVE VEHICLE PERFORMANCE AND ECONOMY SIMULATOR

GPSIM, General Purpose Automotive Vehicle Performance and Economy Simulator, has been under development by the staff of General Motors Corporation since 1960. Its purpose is to simulate automotive vehicle performance and economy.

## SPONSOR

General Motors Corporation

## AUTHOR

William C. Waters
Engineering Staff
General Motors Corporation
Warren, Mich.

## MODEL TYPE

Vehicle operating performance, automobile design

## OBJECTIVE OF MODEL

The general objective of the model is to compute the operating conditions of the engine and transmission and the performance and economy of the vehicle as the vehicle is operated in a prescribed manner.

Specific objectives are:

1) to provide a fast, economical method to compute vehicle performance and economy for production and experimental vehicles;

2) to provide a convenient format to use, with easily understood input and output;

3) to run with a minimum of input data describing the vehicle, but to be able to accept more complete data, if available;

4) to provide for easy location and diagnosis of input data errors.

## RELATIONSHIP TO OTHER MODELS

There is no apparent relationship with other models.

## HISTORICAL BACKGROUND

A vehicle simulation model was first developed by General Motors Engineering Staff in 1960. This model has been under continual development since then, the resulting program being GPSIM.

## ASSUMPTIONS

GPSIM operates under five basic assumptions:

1) Tables can be used instead of a comprehensive set of equations to describe the performance of engines, converters, rotating losses, etc.

2) Steady-state engine and converter tests can be used to predict their dynamic operations.

3) Hydrodynamic laws of similarity apply to the torque converter.

4) Simplified shift models can be used to simulate transmission shifts; that is, the amount of energy transferred during the shift is important, but how it is transferred is unimportant.

5) Steady-state operating capability of a vehicle can be defined with a set of tables, and the operating characteristics of that vehicle can be accurately obtained by referring to these tables.

## VALIDATION

A complete validation of the model has never been done. Several tests have been made, however, which show that for three actual car tests and one simulation with the model, the results of the simulation were within the range of the three tests.

## LIMITATIONS AND BENEFITS

This model may be used to simulate alternative engine types, such as electric vehicles.

## STRUCTURE

This physical or engineering model consists of six basic equations:

$$TE = \frac{(ENGHP - ALOSSES) \times 375}{VMPH}$$

$$ACCEQV = \frac{TE - ROLRES}{WTEQV}$$

$$ACC = (ACCEQV - GRDEQV) \times ACCG$$

$$V = V_1 + ACC \times DT$$

$$D = D_1 + V_1 \times DT + \frac{ACC \times DT^2}{2}$$

$$AMPG = \frac{MILES}{GALLON}$$

where:

ACC = vehicle acceleration ($ft/s^2$)

ACCEQV = equivalent acceleration (g)

ACCG = acceleration of gravity ($32.17/s^2$)

ALOSSES = apparent driveline losses (hp)

AMPG = fuel economy (mpg)

D = distance at end of time interval (ft)

$D_1$ = distance at start of time interval (ft)

DT = length of time interval (s)

ENGHP = gross engine power (hp)

GALLONS = quality of fuel used (gallons)

GRDEQV = acceleration that has the same effect on vehicle as the given grade (g)

MILES = distance traveled (miles)

ROLRES = force required to maintain motion of vehicle on land (lbs)

TE = tractive effort (lbs)

V = vehicle velocity at end of time interval (ft/s)

$V_1$ = vehicle velocity at start of time interval (ft/s)

WTEQV = equivalent weight (lbs)

VMPH = vehicle speed (mph)

## MODEL CONSTRUCTION

The model is based on a set of relationships derived from the basic laws of motion.

## DATA USED IN RUNNING MODEL

Input data are divided into three categories: data blocks, specifications, and commands. A data block is a related group of data that describes a part of the vehicle, a route, a schedule, or some set of actions GPSIM is to take. Specifications are statements which alter the way GPSIM normally operates. A command is a statmement that requires some action by GPSIM.

## DOCUMENTATION

William C. Waters, General Motors Corp., General Purpose Automotive Vehicle Performance and Economy Simulator, Society of Automotive Engineers, Paper No. 720043, January 1972.

## COMPUTER REQUIREMENTS

GPSIM is written in PL/I and was operating (in 1972) on an IBM 360 Model 65 Computer. The program consists of 40 external procedures containing a total of 14,000 source statements. There are 500,000 8-bit bytes of machine instructions that are overlayed into 180,000 bytes of core storage. The range of core requirements is 200,000 to 300,000 bytes. Two to nine external files are used.

# POLICY SEARCH MODEL FOR EVALUATING FUTURE NATIONAL TRANSPORTATION STRATEGIES

The Policy Search Model for Evaluating Future National Transportational Strategies was developed by the Chicago Transit Authority and Northwestern University. The model projects the state of the national transportation system into the future under a variety of energy and environmental constraints.

## AUTHOR

Martin J. Bernard III
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Chicago Transit Authority

Joseph L. Schofer
Civil Engineering
Northwestern University

## MODEL TYPE

Vehicle miles traveled, modal split, energy consumption

## OBJECTIVE OF MODEL

The objective of this energy model is to provide support in the identification, evaluation, and selection of transportation policies at the national level. It projects the state of the national transportation system into the future under a variety of energy and environmental constraints.

## RELATIONSHIP TO OTHER MODELS

The model bears no direct relationship to other transportation models.

## ASSUMPTIONS

State variables are assumed to have default values which limit their maximum feasible increase or decrease. These constraints are based on historical trends and serve as policy and economic limitations on change. The model does not assume an economic growth trend. Rather, any trend, including reverses, may be specified.

## VALIDATION

The model report does not discuss any validation of the model.

## STRUCTURE

The model consists of a linear programming algorithm which maximizes an objective function subject to 121 constraints. The objective function is

$$\text{Max} \left( \sum_{i=1}^{4} a_i x_i + k \sum_{j=1}^{7} b_j y_j \right)$$

where:

$x_i$ = per capita passenger miles by age group i

$y_i$ = per capita ton miles by commodity group j

$a_i$, $b_j$, = priorities for travel report or shipment of a group, set by user

k = priority of passenger miles to ton miles, set by user

The constraints are classified into one of three sets: conservation, proportion, or limitation. A typical limitation constraint is

$$\sum_i a_i x_i \leq b$$

where:

$x_i$ = passenger or ton miles for mode of travel i using a particular energy source

$a_i$ = gallons per ton or passenger mile for mode i, input by user

b = projected supply of energy source, set by user.

The model incorporates 43 modes of transportation. For specified future scenarios, the model computes the most efficient use of each mode of transportation.

## MODEL CONSTRUCTION

The model requires data with which to construct the linear constraints. These data are not included in the model report.

## DATA USED IN RUNNING MODEL

The model requires projections of population, energy availability, and modal energy efficiencies. Values are not indicated in the report. The user must also specify desired shipment and travel priorities and maximum annual system changes.

DOCUMENTATION

Martin J. Bernard III and Joseph L. Schofer, "Policy Search Model for Evaluating Future Transportation Strategies Under Energy and Environmental Constraints," presented at the Intersociety Committee on Transportation Technical Session on Resource/Energy Strategies, Atlanta, July 16, 1975.

COMPUTER REQUIREMENTS

The model runs interactively on the Northwestern University CDC 6400 computer.

# VEHICLE MILES TRAVELED MODEL

A Vehicle Miles Traveled Model was prepared by the Environmental Impact Center (EIC) Inc. for the Transportation Systems Center (TSC) as part of a revision of the TSC's Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model. It is dated March 1976. The revised Integrated Fleet Model examines the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years. TSC has used the model in the Fuel Economy Emissions Impact Study.

## SPONSOR

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## AUTHOR

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## MODEL TYPE

Vehicle miles traveled

## OBJECTIVE OF MODEL

The objective of the model is to provide forecasts of vehicle miles traveled as part of an integrated fleet model designed to examine the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model.

## HISTORICAL BACKGROUND

TSC developed its own integrated fleet model, and later contracted with EIC Corporation to prepare a revised model that rectifies problems in the original model.

## VALIDATION

The author reported that reasonable forecasts were obtained for several alternative future scenarios.

## LIMITATIONS AND BENEFITS

This model is an improvement over the previous TSC vehicle miles traveled model. However, the model does not disaggregate by size of car.

## STRUCTURE

The model consists of an identity defining VMT and a first difference equation for ΔVMT which is estimated by ordinary least squares for annual data from 1953 to 1974. These equations are:

$$VMT = VMT(-1) + \Delta VMT$$

$$\Delta VMT = \underset{(3.2)}{11.293}\,(\Delta HH) + \underset{(4.8)}{.857}\,(\Delta Y) - \underset{(-5.2)}{8273}\,(\Delta COST) - \underset{(-1.4)}{45}\,(\Delta TRANS)$$

$$R^2 = .86$$

where t-statistics are in parentheses, and

VMT = nationwide vehicle miles traveled in billions of miles

VMT(-1) = last year's VMT

Δ = a one-year change in the value of the variables, e.g., ΔVMT = VMT - VMT(-1)

HH = number of households in the U.S., in millions

Y = real disposable personal income, in billions of 1967 dollars

COST = cost per mile of driving, in constant 1967 dollars, = PGAS/MPG

PGAS = real price of gasoline

MPG = average fleet-wide fuel economy in miles per gallon

TRANS = the total supply of transit (rail, trolley, and bus) measured in billions of vehicle miles

## MODEL CONSTRUCTION

The model was calibrated using annual values for the independent variables from 1953 to 1974. The report does not indicate specific data sources.

DATA USED IN RUNNING MODEL

Assumptions are necessary as to the future values for the number of households, disposable income, the cost of driving, and the supply of transit. Alternative assumptions are included in this report.

DOCUMENTATION

EIC Corporation, Refinements to the AEEP Integrated Fleet Model, prepared for TSC, Order No. TS11513, March 29, 1976.

# NEW CAR SALES MODEL

The New Car Sales Model, dated March 1976, was prepared by Environmental Impact Center (EIC) Inc. for the Transportation Systems Center (TSC) as part of a revision of the Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model. The revised Integrated Fleet Model examines the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years. TSC has used the model in the Fuel Economy Emissions Impact Study.

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## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The model forecasts new car demand as part of an integrated fleet model designed to examine the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model.

## HISTORICAL BACKGROUND

TSC developed its own integrated fleet model, and later contracted with EIC Corporation to prepare a revised version that rectifies problems in the original.

ASSUMPTIONS

The model assumes a linear functional form, which implies that elasticities are proportional to the values of the respective variables. It also assumes that the demand for new cars is derived from the demand for travel, as specified in the vehicle miles traveled variable.

VALIDATION

The authors reported that reasonable forecasts were obtained for several alternative future scenarios.

LIMITATIONS AND BENEFITS

This model includes improvements in equation specification over a previous TSC new car sales model; however, it does not disaggregate by size of car.

STRUCTURE

This econometric model consists of a single equation explaining new car sales in terms of five independent variables, including the value of VMT. The equation is estimated using ordinary least squares.

$$\begin{aligned} NCAR = \underset{(2.7)}{3.94} - \underset{(-1.7)}{.00103}\,(RPSTK) + \underset{(6.7)}{.0594}\,(\Delta Y) - \underset{(-3.1)}{.311}\,(u) \\ + \underset{(3.1)}{.766}\,(STRIKE) + \underset{(16.2)}{.00849}\,(VMT) \end{aligned}$$

$R^2 = .95$ DW = 2.15

where t-statistics are in parentheses, and

NCAR = annual new car sales in millions of cars

RPSTK = the sticker price of new cars in constant 1967 dollars

$\Delta Y$ = annual change in real disposable personal income in billions of constant 1967 dollars

u = deviations from "normal" levels of unemployment (unemployment rate - 4.0)

STRIKE = dummy variable for strikes in automobile industry, = -1 in year of the strike, = 0 otherwise

VMT = annual national vehicle miles of travel measured in billions of miles.

## MODEL CONSTRUCTION

The model was calibrated using annual values for the variables from 1953 to 1974. No specific data sources are indicated in this report, except for new car price, which came from Ward's Automotive Yearbook, for domestic car prices only.

## DATA USED IN RUNNING MODEL

To run this submodel, the forecast of vehicle miles traveled (VMT) from the VMT submodel is necessary, as are forecasts of new car price, income change, and unemployment.

## DOCUMENTATION

EIC Corporation, Refinements to the AEEP Integrated Fleet Model, prepared for TSC, Order No. TS11513, March 29, 1976.

# FLEET MODEL

The Fleet Model, dated March 1976, was prepared for Transportation Systems Center (TSC) by the Environmental Impact Center (EIC) Inc. as part of a revision of the Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model. The revised model examines the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years. TSC has used the model in the Fuel Economy Emissions Impact Study.

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## AUTHOR

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## MODEL TYPE

Fleet Size

## OBJECTIVE OF MODEL

The model forecasts automobile fleet size as part of an integrated fleet model designed to examine the overall impact of alternative energy and emissions policies on vehicle miles traveled, new car sales, fleet size, fuel economy, total fuel consumption, and air quality over the next fifteen years.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Automotive Energy Efficiency Program (AEEP) Integrated Fleet Model.

## HISTORICAL BACKGROUND

TSC developed its own integrated fleet model, and later contracted with EIC Corporation to prepare a revised model that rectifies a number of problems with equation specification in the original model.

## ASSUMPTIONS

The model assumes that a stock adjustment mechanism determines fleet size.

## VALIDATION

The authors reported that reasonable forecasts were obtained for several alternative future scenarios.

## LIMITATIONS AND BENEFITS

This model includes improvements in the specification of equations over a previous fleet model. It does not include determinants of the scrappage rate. The model does not disaggregate by size of car.

## STRUCTURE

This econometric model consists of a single trend-type fleet equation estimated by ordinary least squares.

$$\underset{}{\text{FLEET}} = \underset{(-2.3)}{-10.8} + \underset{(7.4)}{.667}\,[\text{FLEET}(-1)] + \underset{(2.4)}{.0160}\,(Y) + \underset{(2.7)}{.473}\,(HH)$$

$R^2 = .999$

where t-statistics are in parentheses, and

FLEET = the total number of cars registered in millions

FLEET(-1) = last year's fleet size

Y = real disposable personal income measured in billions of constant 1967 dollars

HH = number of households in U.S. in millions

## MODEL CONSTRUCTION

The model was calibrated using annual values for the independent variables from 1953 to 1974. This report does not indicate specific data sources.

## DATA USED IN RUNNING MODEL

Forecasts of income and number of households are required.

DOCUMENTATION

EIC Corporation, Refinements to the AEEP Integrated Fleet Model, prepared for TSC, Order No. TS11513, March 29, 1976.

# APS: AUTOMOTIVE PROPULSION SIMULATOR

The Automotive Propulsion Simulator (APS) was developed in 1974 at the University of Wisconsin under the sponsorship of the U.S. Department of Transportation. It simulates the physical systems of automobile engines and transmissions, using a dynamic digital computer program and a real-time program with input from a human "driver." It may be used to model fuel consumption, emissions, and vehicle operating performance.

## SPONSOR

U.S. Department of Transportation
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## AUTHOR

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## MODEL TYPE

Emissions, fuel economy, air pollution/air quality, vehicle operating performance

## OBJECTIVE OF MODEL

The model is designed to simulate dynamically vehicle fuel consumption, emissions, and other performance characteristics. It may be used to test the performance of engines of varying types (including alternative power plants) and specifications.

## RELATIONSHIP TO OTHER MODELS

In addition to the APS digital computer program, there is a real-time interactive program attached to a driving simulator. A human operator's reactions to engine and tire noise can thus be used as human factors inputs to the model, resulting in a more realistic simulation.

## ASSUMPTIONS

The model is calibrated according to the proven performance specifications of a set of automobiles. Where data are not available, certain conditions are assumed. For example, there is no automatic choke information, so the vehicle is assumed to start out completely warmed to operating temperatures.

## VALIDATION

Simulations of vehicle engines were compared with measurements made of the actual performance of these engines. Predicted and actual values for MPG fuel consumption are quite close, but are less so for emissions.

## LIMITATIONS AND BENEFITS

The model depends on the specifications of engine performance that can be acquired and used to build its various components. These data are not readily available, as they may come only from auto manufacturers. As new data are acquired, however, the model can be expanded to include new engine components to be simulated.

## STRUCTURE

This is a physical system model. The human driver or the automatic driver provides a throttle setting. This, with engine speed, produces engine torque, which is combined with transmission torque and accessory demand, to compute engine acceleration. Engine speed, torque converter output, transmission torque, rear axle and tractive torque are then computed. This is combined with road load to get vehicle acceleration after the effective vehicle mass has been found. Velocity, driveshaft speed, and torque-converter-output-speed are obtained, and a new engine torque is thus computed. This cycle is repeated ten times per second. Fuel consumption and emissions are computed as a function of engine speed and torque at every instant.

## MODEL CONSTRUCTION

Complete vehicle specifications on five autos and emissions maps on several others were used to build the model. Data are presented in graph form in the model report.

## DATA USED IN RUNNING MODEL

Engine size factors, torque ratios, and other engine parameters are inputs to the model.

## DOCUMENTATION

N.H. Beachley and A.A. Frank, Increased Fuel Economy in Transportation Systems by Use of Energy Management, Final Report, Vols. I-III, Department of Transportation, Report No. DOT-TST-75-2, Dec. 1974. NTIS No. PB-248 777.

## COMPUTER REQUIREMENTS

Vols. II and III of the model report provide a detailed explanation of the structure of the programs and exhaustively documented copies of the program code. The programs are written in FORTRAN II. Vol. II contains the Automotive Simulation Program and the Performance Analysis Program. Vol. III contains the Real-Time (Hydrid and Computer) Simulation Program.

# MATERIALS AND ENERGY RESOURCE ACCOUNTING MODEL (ARAM)

The Materials and Energy Resource Accounting Model (ARAM), dated February 1976, was prepared by The Charles Stark Draper Laboratory, Inc. for the Transportation Systems Center of the U.S. Department of Transportation. It forecasts the future materials and energy requirements for alternative automobile technologies. ARAM is a submodel of the Resources Accounting Model, which has been used by the Task Force on Motor Vehicle Goals Beyond 1980 for impact assessment of future automobile production and usage scenarios as part of the overall effort to examine long-range energy goals for the motor vehicle fleet that are compatible with environmental, safety, and economic objectives.

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## MODEL TYPE

Vehicle manufacturing resource utilization, energy consumption

## OBJECTIVE OF MODEL

The objective of the model is to assess the impact of future automobile technology options on resources. It tracks the total scenario of resource requirements for materials and energy and presents this information for assessment.

## RELATIONSHIP TO OTHER MODELS

The model is a submodel of the Resources Accounting Model, which is part of the overall modeling effort undertaken by the Task Force on Motor Vehicle Goals Beyond 1980. ARAM requires input from the Fleet Model (76-007).

## HISTORICAL BACKGROUND

The Task Force on Motor Vehicle Goals Beyond 1980 was created in May 1975 to examine long-range energy goals for the motor vehicle fleet that are compatible with environmental, safety, and economic objectives.

## ASSUMPTIONS

The model assumes that the efficiency of converting heat energy to electricity is 40%. Also, the model assumes annual values for the net import fraction of each type of auto. The model excludes net car imports from the materials and energy calculations.

## VALIDATION

The model report does not indicate whether any validation of the model was performed.

## STRUCTURE

This model employs a family-tree approach to resource accounting. It traces materials or energy types on a physical unit basis from their finished form back through intermediate stages of production to their raw material origins. The model forecasts the annual demand for imported processed materials, imported raw materials, domestic raw materials, and domestic scrap materials, and it forecasts the energy requirements for the processing of the materials, the fabrication of the automobiles, and the operation of the automobiles. The model itself consists of a set of 24 accounting relationships. A representative equation appears below:

$$TMP_{jk} = \sum_i (P_{ik})(QM_{ijk})$$

where:

$i$ = an index of family type of automobile

$j$ = an index of materials

$k$ = an index of years

$TMP_{jk}$ = annual materials requirements for domestic auto production

$P_{ik}$ = all classes of vehicles of family i produced in year k

$QM_{ijk}$ = weighted average of material j requirement over all classes of vehicles of family i produced in year k

## MODEL CONSTRUCTION

The model includes internal data on the energy required for materials processing, the materials waste ratio, the scrap fraction, and import fractions for both processed and raw material imports. The data values for a first set of scenarios for a variety of materials, including metals, glass, rubber, plastics, paints, etc. are included in the model report. The sources for these data were reports from the Chrysler Corporation, the University of Chicago, the National Commission on Materials Policy, and the Department of Commerce.

## DATA USED IN RUNNING MODEL

The model requires input data from three sources:

1) Internal data are required on materials processing energy, the materials waste ratio, the scrap fraction, and import fractions for both processed and raw material imports. Values used and the data sources appear in the model report on pp. 13-17.

2) Input is required from another program, MATCOM, on the required weight of each material per auto and on fabrication energy requirements per auto. MATCOM calculates per-vehicle material requirements based on given curb weight, vehicle structure, and engine type.

3) Input data are required from the Fleet Accounting Model (another submodel of the Resources Accounting Model) for annual sales by auto family type and class, for autos retired annually by type and class, and for the annual gallons of fuel necessary to operate all autos by type and class.

## DOCUMENTATION

J. Barton DeWolf, Christian Davis, Peter C. Heinemann, and John T. Prohaska, Computer-Based Resource Accounting Model for Automobile Technology Impact Assessment, Draft, prepared by The Charles Stark Draper Laboratory, Inc., for TSC under Contract No. DOT-TSC-1021, February 1976.

Bruce Rubinger and Simon Prensky, A Computer-Based Resource Accounting Model for Generating the Aggregate Resource Impacts of Alternative Automobile Technologies, TSC, Working Paper, Report No. DOT-TSC-OS-714-WP-77-7, June 1977.

## COMPUTER REQUIREMENTS

The computer programs are written in FORTRAN and PL/1, and were designed to run on an IBM 360/75.

# CAPITAL AND LABOR RESOURCE ACCOUNTING MODEL (INRAM)

The Capital and Labor Resource Accounting Model (INRAM), dated February 1976, was prepared by The Charles Stark Draper Laboratory, Inc., for the Transportation Systems Center (TSC). It computes total future capital and labor requirements for the automobile industry based on possible future automotive technologies. The Task Force on Motor Vehicle Goals Beyond 1980 used the model for impact assessment as part of the overall effort to examine long-range energy goals for the motor vehicle fleet that are compatible with environmental, safety, and economic objectives.

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## AUTHOR

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## MODEL TYPE

Vehicle manufacturing resource utilization

## OBJECTIVE OF MODEL

The model computes total future capital and labor requirements for the automobile industry based on possible future automotive technologies.

## RELATIONSHIP TO OTHER MODELS

This model is a submodel of the Resource Accounting Model, which is part of the overall modeling effort undertaken by the Task Force on Motor Vehicle Goals Beyond 1980. It uses input-output analysis to predict future capital and labor requirements. The basic input-output model, INFORUM, was developed at the University of Maryland by C. Almon. An input-output model incorporates coefficients describing the inter-industry and final demand flow of products in the economy. INRAM utilizes data supplied by ARAM (76-024A) to alter selected coefficients in Almon's model as required by the different economic and technological environment induced by a given scenario.

HISTORICAL BACKGROUND

The Task Force on Motor Vehicle Goals Beyond 1980 was created in May 1975 to examine long-range energy goals for the motor vehicle fleet that are compatible with environmental, safety, and economic objectives.

ASSUMPTIONS

The model assumes that the input-output methodology is appropriate for forecasting the capital and labor requirements of various automobile technology and usage scenarios. Also, it presently assumes that only a limited number of coefficients in Almon's model require modification.

VALIDATION

The model report notes that the input coefficient modification equations are being validated on historical data. In the existing report they are unvalidated.

STRUCTURE

The model uses input-output analysis to predict capital and labor requirements. Fourteen coefficients from the INFORUM Model were modified in the INRAM report. The general formula for computing modifications appears below:

$$A^{k}_{ij} = A^{75}_{ij} \left[R_{ij} \left(\frac{TM^{k}_{ij}/p^{k}}{TM^{75}_{ij}/p^{75}}\right) + (1 - R_{ij})\right]$$

where:

$A^{k}_{ij}$ = input-output coefficient in year k for the ith producing industry and the jth consuming industry

$A^{75}_{ij}$ = base year (1975) value of the coefficient

$R_{ij}$ = fraction of output in industry j which is used in the production of new autos

$TM^{k}_{ij}$ = material in physical units used in industry j as produced in industry i for the annual production of autos in year k

$p^{k}$ = number of autos produced in year k

$TM^{75}_{ij}$ = base year (1975) value of material in physical units consumed by industry j as produced by industry i for the production of new autos

$p^{75}$ = base year (1975) number of autos produced

Preliminary market share values were assumed for R based on 1972 data. Almon's model currently produces output for 1972 to 1985.

## MODEL CONSTRUCTION

Almon's input-output model requires a large amount of data, which are incorporated into the computer program. INRAM requires ARAM output, so that all data necessary to build ARAM must be available.

Data are also required on motor vehicle capital investment requirements. These do not appear in the model report.

## DATA USED IN RUNNING MODEL

Annual forecasts from ARAM are required for: requirements for up to thirty materials used in domestic auto production, number of autos produced domestically, new car sales, and fleet operating energy.

The input-output model requires exogenous assumptions regarding the future annual values of disposable income per capita, population, long-term investment rate, rent/construction cost index, households, investment tax credit, average foreign currency price, labor force, and civilian unemployment rate.

## DOCUMENTATION

J. Barton DeWolf, Christian Davis, Peter Heineman, and John T. Prohaska, Computer-Based Resource Accounting Model for Automobile Technology Impact Assessment, Draft, Vol. I, prepared by the Charles Stark Draper Laboratory, Inc., for TSC under Contract No. DOT-TSC-1021, February 1976.

C. Almon et. al., 1985: Interindustry Forecasts of the American Economy, Lexington Books, Lexington, Mass., 1974.

Bruce Rubinger and Simon Prensky, A Computer-Based Resource Accounting Model for Generating the Aggregate Resource Impacts of Alternative Automobile Technologies, TSC, Working Paper, Report No. DOT-TSC-OS-714-WP-77-7, June 1977.

## COMPUTER REQUIREMENTS

Almon's input-output model is designed to run on a UNIVAC 1106 with an EXEC 8 operating system. The model is quite large.

# CRA HEDONIC MARKET SHARE MODEL

The CRA Hedonic Market Share Model, dated October 1976, was prepared by Charles River Associates (CRA), Inc. for the Bureau of International Labor Affairs, Department of Labor (DOL). The model estimates the effects of changes in imported car prices on foreign and domestic automobile market shares. CRA and DOL have used the model as part of an assessment of economic effects of potential changes in U.S. tariffs and of the imposition of quotas by the U.S. on imports of foreign cars. The model is also being used by CRA for the National Highway Traffic Safety Administration in a study of the impact of fuel economy and car size on market shares and competition among automobile companies.

## SPONSOR

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## MODEL TYPE

Pricing, market share, vehicle manufacturing resource utilization, automobile demand

## OBJECTIVE OF MODEL

The model estimates the effects of changes in imported car prices on foreign and domestic market shares, domestic automobile production and prices, and employment in the U.S. automobile industry.

## RELATIONSHIP TO OTHER MODELS

The model has no relationship to other models.

## HISTORICAL BACKGROUND

Current trade barriers against automobile imports are low. This study was prompted by increased public and Congressional interest in using trade barriers to reduce unemployment, which had resulted from the 1974-75 slump in the U.S. automobile industry.

ASSUMPTIONS

The estimating technique assumes that individual consumers vary in their demand for particular automobile characteristics, including price, because of differences in income, use patterns, and personal tastes. The model also assumes that market size is fixed and that the utility function is linear. Finally, it assumes that consumer tastes are stable as prices are changing.

VALIDATION

The predictions derived from the model have not been validated by comparison with actual historical experience. The author does note that the results are similar to estimates from time series regressions included in the report and to predictions derived by questionnaire techniques in a study by Market Facts, Inc.

LIMITATIONS AND BENEFITS

For the share estimates to be reasonable, the set of automobile models included must cover nearly the entire market. Also, in order to estimate new car sales, estimates of the total price elasticity of new car demand must be obtained from other sources.

STRUCTURE

The model estimates the distribution of consumer tastes and then uses the estimates to predict the market share distribution produced by a change in prices and characteristics of automobiles. The model is too extensive to reproduce here in its entirety. Therefore, a brief discussion follows.

The model begins with the assumption:

$$U_{ij} = U(C_j, P_j, \alpha_i)$$

where:

$U_{ij}$ = is the utility of individual consumer i from purchase of model j

$C_j$ = is a vector of characteristics of model j

$P_j$ = is the price of model j

$\alpha_i$ = is a set of parameters mapping $C_j$ and $P_j$ into $U_{ij}$

The utility function is assumed to be linear, so that the $\alpha_i$'s represent marginal rates of substitution between the characteristics and price. Then $\alpha$ is viewed as a vector of random variables, generating a probability distribution for the choice among automobile models.

The model assumes a simple functional form for the probability distribution of the $\alpha$'s, and seeks to find the distribution of consumers' utility functions which reproduces the market shares actually observed for individual models.

## MODEL CONSTRUCTION

This model is constructed on input data, including price, physical characteristics, and new car sales between April 1974 and August 1974 for 106 car makes and models. A list of the variables and data sources appears in the model report.

## DATA USED IN RUNNING MODEL

Forecasts of the increase in import prices and the prices and characteristics of new cars by market segment are necessary to run the model.

## DOCUMENTATION

Charles River Associates, Impact of Trade Policies on the U.S. Automobile Market, prepared for Bureau of International Labor Affairs, U.S. Department of Labor, CRA Report No. 219, October 1976.

Charles River Associates, The Development of a Methodology for Predicting the Demand for New Goods with Illustrative Applications to Residential Heat Pumps, under Contract No. RP 488-1 for the Electric Power Research Institute, July 1976.

## COMPUTER REQUIREMENTS

The computer program consists of an algorithm for numerical evaluation of probability integrals using the Monte-Carlo method. The computer program is written in machine code, and it requires several hand calculations at various points in the maximum likelihood and Monte-Carlo procedures.

# SPECULATER: SIMULATION PROGRAM EXAMINING THE CAUSALITIES UNDERLYING LAND, AGRICULTURE, TRANSPORTATION, AND ENERGY RELATIONSHIPS

The SPECULATER model, prepared in 1975 at the University of California at Davis, simulates the relationships between urban and national transportation, the oil industry, and the wheat industry. The project was sponsored by the National Science Foundation. The model can be used to predict fuel consumption and transportation modal split using a variety of transportation-related and non-transportation-related assumptions.

## SPONSOR

Research Applied to National Needs
National Science Foundation
Washington, D.C. 20550

## AUTHOR

J.W. Young, J.L. Mitchener, K.E.F. Watt, et al.
University of California
Institute of Ecology
Interdisciplinary Systems Group
Davis, Calif. 95616

## MODEL TYPE

Vehicle miles traveled, vehicle user costs/vehicle operating costs, energy consumption, modal split

## OBJECTIVE OF MODEL

The model predicts oil and gas consumption, modal split, and urban and agricultural land area, under the basic assumption that agricultural exports will increase to offset the unfavorable trade balance due to increased fuel imports.

## RELATIONSHIP TO OTHER MODELS

This model's simulation is national in scope. Some of its outputs are used in the accompanying regional-scope model SAM: Sacramento Area Model (75-027B).

## HISTORICAL BACKGROUND

K.E.F. Watt, The Titanic Effect, 1974, originally described the relationship between petroleum imports and agricultural exports. This relationship was used as one of the major hypotheses in designing the model.

## ASSUMPTIONS

The basic assumption is that U.S. wheat exports will be increased and encouraged in order to offset the unfavorable balance of trade due to the high cost of oil imports.

## VALIDATION

A large variety of scenarios using different input levels of the exogenous variables were run. Most of the following conditions were found to be unaffected by the scenarios used: the rate of urban sprawl, the urban population density, the adequacy of U.S. food supply, the increased use of public transportation, a decrease in energy consumption, and an increase in agricultural activity.

## LIMITATIONS AND BENEFITS

The report describing the model includes sections on the theory and methodology of simulation modeling, which would be of aid in modifying this model or building other models. This model is unconventional in that it draws relationships between very indirectly related segments of the economy.

## STRUCTURE

Numerous interlocking relationships are described between several sectors of the economy, including the national transportation industry, the oil industry, the wheat industry, and the composite urban area, which is made up of 101 cities containing 43% of the U.S. population. Variables involved include: the prices of fuels and grains, population, the volume of imports and exports, consumption, production, transportation modal splits, and the rate of land conversion from agricultural to urban use. The volume of wheat exports is partly a function of the cost of oil imports, implying a political relationship in what is otherwise an algebraic model.

## MODEL CONSTRUCTION

This is a dynamic simulation operations research model, describing cause and effect relationships. Actual historical data have been used to identify parameters. The numerous equations and parameters for each variable used in the model are described in the text of the model report.

## DATA USED IN RUNNING MODEL

The following variables are exogenous to the model, and their values are supplied in the report: migration rates, price of gasoline, mode availability, population growth rate, price of corn, U.S. oil production, price of imported oil, residual foreign demand for wheat, and wheat yields.

## DOCUMENTATION

J.W. Young, et al., Land Use, Energy Flow, and Policy Making in Society: Final Report, University of California at Davis, September 1, 1975. NTIS No. PB-251 537.

## COMPUTER REQUIREMENTS

A user's manual and card deck consistent with an IBM 360/370 machine are available from John W. Brewer, University of California, Davis, California 95616.

# SACRAMENTO AREA MODEL (SAM)

The Sacramento Area Model (SAM) is meant to be used in conjunction with the SPECULATER model. Both were developed at the University of California at Davis, in 1975, under a grant from the National Science Foundation. The model can be used to predict vehicle miles traveled and modal split for a metropolitan region given a variety of transportation-related and non-transportation-related assumptions.

## SPONSOR

Research Applied to National Needs
National Science Foundation
Washington, D.C. 20550

## AUTHOR

J.W. Young, J.L. Mitchener, K.E.F. Watt, et al.
University of California
Institute of Ecology
Interdisciplinary Systems Group
Davis, Calif. 95616

## MODEL TYPE

Vehicle miles traveled, vehicle user costs/vehicle operating costs, energy consumption, modal split

## OBJECTIVE OF MODEL

The model predicts vehicle miles traveled per capita, public transit usage per capita, freeway and public transit availability, and land conversion rate.

## RELATIONSHIP TO OTHER MODELS

This model is regional in scope and uses outputs from the accompanying national-scope model, SPECULATER (75-027A).

## ASSUMPTIONS

As this model uses results from SPECULATER as inputs, any combination of national-level assumptions can be used as inputs to it. Assumptions may be made about the availability of transportation modes in a metropolitan region.

VALIDATION

A large variety of scenarios using different input levels of the exogenous variables and of the results from the SPECULATER model were used in model runs. It was found that the level of public transit usage was affected by the price of gasoline.

LIMITATIONS AND BENEFITS

This model can be used, in conjunction with SPECULATER, to examine the effects of national phenomena on a local regional area and to evaluate local strategies. While it was developed for the Sacramento area, it is probably transferrable to other regions of the country.

One limitation of the model is that if output from SPECULATER is used as input to SAM, then the quality of forecasts from SAM are contingent upon the quality of SPECULATER.

STRUCTURE

The model was designed with the Sacramento, Calif. metropolitan area in mind, but presumably could be used for other regions. Urban area transportation mode availability, transportation fuel supply per capita, and per capita transportation fuel consumption are input as results from SPECULATER. Transit funding, employment location index, transit fare, and demographic variables are exogenous. Public transit and freeway availability and the land conversion rate (agricultural use to urban use) may be either exogenous or predicted variables.

MODEL CONSTRUCTION

This is a dynamic simulation operations research model, describing cause and effect relationships. Actual historical data have been used to identify parameters. Equations and parameters for each variable used in the model are described in the model report.

DATA USED IN RUNNING MODEL

The numerous equations and parameters for each variable used in running the model are described in the model report. Data must be supplied for demographic and transit availability variables.

DOCUMENTATION

J.W. Young, et al. Land Use, Energy Flow, and Policy Making in Society: Final Report, University of California at Davis, September 1, 1975. NTIS No. PB-251 537.

COMPUTER REQUIREMENTS

A User's Manual and card deck consistent with an IBM 360/370 machine are available from John W. Brewer, University of California, Davis, Calif. 95616.

# TRANSPORTATION AND AIR SHED SIMULATION MODEL (TASSIM MODEL)

The Transportation and Air Shed Simulation Model (TASSIM) integrates an urban transportation planning model, vehicle emission factors, and simple air diffusion models in a simulation framework that can be used to analyze the air quality effects of transportation policies. It was developed in 1974 at Harvard University under the sponsorship of the U.S. Department of Transportation. The model was used in 1974 by the National Academy of Sciences in the report, The Costs and Benefits of Automobile Emission Control, prepared for the U.S. Senate Committee on Public Works. It has also been used to evaluate the impact of various transportation policies in the Boston and Los Angeles areas.

## SPONSOR

U.S. Department of Transportation
Office of the Secretary
Washington, D.C. 20590

## AUTHOR

Gregory K. Ingram and Gary R. Fauth
Harvard University
Cambridge, Mass. 02138

## MODEL TYPE

Air pollution/air quality, emissions

## OBJECTIVE OF MODEL

The objective of the TASSIM model is to integrate an urban transportation model, vehicle emission factors, and simple air diffusion models in a simulation framework that can be used to analyze the impacts of various transportation policies on air quality. The model is capable of simulating concentrations of carbon monoxide, hydrocarbons, oxides of nitrogen, and particulate matter in as many as 200 distinct zones within a metropolitan area.

## RELATIONSHIP TO OTHER MODELS

The model is constructed to be compatible with the Federal Highway Administration's standard Urban Transportation Planning (UTP) model in order to minimize data problems and to insure that parameters from existing models can be used.

## HISTORICAL BACKGROUND

The TASSIM model was originally developed under a university research grant from the National Science Foundation entitled "The Automobile and the Regulation of its Impact on the Environment." The model was improved, expanded, and calibrated under a contract from the Department of Transportation.

## VALIDATION

Calculated annual air quality values from the TASSIM model were compared with 1971 annual measurements from eighteen monitoring sites in the Boston region. The results for sulfur dioxide and particulate matter were fairly consistent. The results for the oxides of nitrogen were not as consistent. This problem is attributed to the sampling technique of this pollutant.

## LIMITATIONS AND BENEFITS

Two primary automotive pollutants, hydrocarbons and oxides of nitrogen, combine in the presence of sunlight to form photochemical oxidants. Although photochemical oxidants are important secondary pollutants, the reaction processes to produce these pollutants are not well known and, therefore, these processes are not represented in the model.

## STRUCTURE

The TASSIM model is comprised of three major components: a transportation submodel, an emission submodel, and an air diffusion submodel.

The transportation submodel forecasts the interzonal distribution of trips and then distributes the trips over the highway and transit network. Included in this model are the calculation of auto vehicle miles traveled per zone as well as auto vehicle cold starts per zone. These variables are necessary inputs to the emission submodel.

The emission submodel transforms information on vehicle flows and speeds in each area into area emissions. The speeds on each link of the transportation network are exogenous, and the relation between vehicle speed and emissions per mile is based on functions compiled by the Environmental Protection Agency.

The diffusion submodel generates pollutant concentrations in each zone based on emissions and meteorological factors.

## MODEL CONSTRUCTION

The model must be calibrated for each region to which it is applied.

The types of data needed include trip generation equation parameters, socio-economic data for each zone, average annual wind speed, the percentage of time the wind is blowing in each of sixteen directions, non-mobile area source emissions by zone for each pollutant, modal split information, etc.

DATA USED IN RUNNING MODEL

Essentially the data necessary to calibrate the model are also required to run the model.

DOCUMENTATION

Gregory Ingram and Gary Fauth, TASSIM: A Transportation and Air Shed Simulation Model, Vol. I: Case Study of the Boston Region, prepared for DOT, May 1974. NTIS No. PB-232 933.

Gregory Ingram and Gary Fauth, TASSIM: A Transportation and Air Shed Simulation Model, Vol. II: Program User's Guide, prepared for DOT, May 1974. NTIS No. PB-232 934.

Gary Fauth and Eugene Kroch, Additional Traffic Assignment Options for the TASSIM Model, prepared for DOT, November 1975.

Frank P. Grad, et al., The Automobile and the Regulation of its Impact on the Environment, University of Oklahoma Press, 1975.

COMPUTER REQUIREMENTS

The model is written in FORTRAN and was designed to be run on an IBM 370. The source code may be obtained from the model authors at Harvard University.

# CONSUMER DEMAND FOR CARS IN THE USA

The Consumer Demand for Cars in the USA model was prepared in 1975 at Cambridge University. The objective of the model is to examine the factors that determine the consumer demand for automobiles in the United States.

## AUTHOR

Ron P. Smith
Department of Applied Economics
Cambridge University
Cambridge, England

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to examine the factors that determine the consumer demand for automobiles in the United States. The entire study is primarily intended to provide a connected account of the automobile market that will be useful to anyone interested in the industry.

## RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

## HISTORICAL BACKGROUND

This study was prepared as the author's Ph.D. thesis at Cambridge University. Some of the work was performed at MIT, where he was a Kennedy Scholar.

## ASSUMPTIONS

The study is comprised of three parts: ownership, replacement, and purchase of automobile models. The ownership model assumes that time-series responses can be derived from cross-section estimates. The model omits cost as an explanatory variable and assumes a positive ownership probability for incomes above zero.

The replacement model assumes a low elasticity of substitution between new and used cars, so that stock depletion cannot explain replacement purchases of new cars.

The short-run purchases model assumes that consumers respond to personal expectations, as reflected in survey attitude indicators, and to confidence in the economy as a whole, as reflected in macro-economic indicators.

## VALIDATION

The author compares his results with those from a number of other studies. The ownership model generates predictions which do not agree well with actual pre-World War II data.

## LIMITATIONS AND BENEFITS

The model is not designed as a complete econometric set of forecasting equations. In fact, the author cautions that the ownership model may not be appropriate for extrapolation purposes. The model does present a new interpretation of the replacement demand for autos, and it emphasizes the importance of consumer expectations for short-run demand prediction.

## STRUCTURE

This study develops and estimates three complementary econometric models that explain ownership, replacement, and purchase of automobiles. The ownership model explains the proportion of single- and multiple-car families by income group in terms of income and time trends. The equation below is estimated using generalized least squares for pooled cross-section and time series data for 1953-69.

$$P(Q_{jt}) = \underset{(-3.3)}{-6.254} - \underset{(-3.9)}{.1157}\,(t) + \underset{(18.7)}{.8264}\,[\log(Y_{jt})] + \underset{(4.3)}{.01495}\,(t)\,[\log(Y_{jt})] - \underset{(-3.9)}{.2466}\,(D)$$

$R^2 = .969$

where t-statistics are in parentheses, and

$P(q_{jt})$ = proportion of families in income group j who own a car in year t

t = time trend

$Y_{jt}$ = mean real income by income group j in year t

D = dummy variable with value 1 prior to 1963, and 0 elsewhere

The replacement model which follows is estimated using ordinary least squares for annual data from 1950 to 1969.

$$\log(U) = \underset{(22.4)}{.9905} [\log(G)] - \underset{(-2.5)}{.1913} [\log(\frac{P}{P_{-1}})] + \underset{(3.0)}{.3757} [\log(\frac{Y}{Y_{-1}})]$$

$R^2 = .90$ DW = 2.2

where t-statistics are in parentheses, and

U = new car purchases for replacement

G = normal replacement pressure

P = new car price index

Y = real disposable income per capita

Finally, data disaggregated by income group are used to estimate several equations relevant to the short-run purchase demand for automobiles. Expectations are explicitly included in the model, leading to the conclusion that no stable demand function exists in the short run.

## MODEL CONSTRUCTION

This model is calibrated using annual data for various periods in the 1950s and 1960s on a number of variables, including income, population, price of new cars, and consumer attitudes. The data sources and actual data values appear in the model report.

## DATA USED IN RUNNING MODEL

The model requires forecasts of the future values of all independent variables.

## DOCUMENTATION

R.P. Smith, Consumer Demand for Cars in the USA, Cambridge University Press, Cambridge, England, 1975.

# ENGINEERING MODEL OF FUTURE MOTOR VEHICLES (EMFMV)

The Engineering Model of Future Motor Vehicles (EMFMV) was prepared by Volkswagenwerk AG in February 1977 for the U.S. Department of Transportation. The objective of the model is to project vehicle weight changes caused by planned alterations of certain substructures in order to increase vehicle safety.

## SPONSOR

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

## AUTHOR

H. Danckert, H.W. Grove, and R. Schmidt
Volkswagenwerk AG
Research Division
3180 Wolfsburg
Germany

## MODEL TYPE

Automobile design, vehicle operating performance

## OBJECTIVE OF MODEL

The objective of the model is to project vehicle weight changes caused by planned alterations of certain substructures in order to increase vehicle safety.

## RELATIONSHIP TO OTHER MODELS

The model bears no direct relationship to other models.

## HISTORICAL BACKGROUND

The objective of the study was to develop a comprehensive engineering model of future motor vehicles which provides a realistic and uniform basis for developing safety requirements and assessing their future effects.

## ASSUMPTIONS

The weight-weight interdependency analysis incorporates the following assumptions:

1) Vehicle structure is optimized according to the state of the art.

2) Design change does not influence the main geometric dimensions of the body structure.

3) Changes in weight of a subsystem require changes throughout the vehicle body.

4) Static deformation of the vehicle will be held constant in the new models.

## VALIDATION

No specific validation efforts are indicated in the model report. However, the report states that the regression analysis of subsystem weight changes has been validated in Don Adams, et al., "High Strength Materials and Vehicle Weight Reduction Analysis," SAE 750 221, Detroit, Mich., February 1975.

## LIMITATIONS AND BENEFITS

The weight-weight interdependency analysis applies only to slight load redistributions and moderate design changes.

## STRUCTURE

The EMFMV contains an extensive data base consisting of up to 104 variables for approximately 4,000 individual automobile makes and models from 1965 to 1976. The data available are classified as descriptive vehicle data, exterior dimensions data, interior dimensions data for the engine, luggage compartment, and passenger compartment, weight data, or other engineering data. For hypothetical weight changes in vehicle components, instituted for reasons of safety or economy, the model calculates secondary weight changes and the new vehicle weight distribution. This calculation can be performed by a regression analysis of the following form:

$$\log(m_i) = \log(a_{0i}) + a_{1i}\,[\log(m)]$$

where:

$m_i$ = mass of subsystem i

m = total vehicle mass

Dependent and independent variables are selected as appropriate. Alternatively, a non-statistical weight-weight estimation procedure is employed. This procedure increases sheet-metal thickness in proportion to the increased external forces acting on each component, thus maintaining constant static deformation. This procedure produces new body subsystem weights, and the regression analysis is then used to determine chassis subsystem weight changes.

## MODEL CONSTRUCTION

This engineering model requires up to 104 variables for approximately 4,000 individual automobile makes and models from 1965 to 1976. These data are not readily available.

## DATA USED IN RUNNING MODEL

Assumptions are required a⌣ to the increase in weight of selected vehicle subsystems.

## DOCUMENTATION

H. Danckert, H.W. Grove, and R. Schmidt, Engineering Model of Future Motor Vehicles, prepared by Volkswagenwerk AG for the U.S. Department of Transportation, Report No. DOT HS-802-290, February 1977.

## COMPUTER REQUIREMENTS

The program is available, for a fee, on the McDonnell Douglas Automation Company (MCAUTO) computer system in St. Louis. A program listing in FORTRAN IV is included in the model report.

# DEMAND FOR NEW AUTOMOBILES IN THE UNITED STATES 1929-1956

A model of the Demand for New Automobiles in the United States 1929-1956 was developed at the University of Michigan in 1958 under a grant from the Ford Motor Company. The objective of the model is to formulate a demand function for automobiles that incorporates consumer credit conditions and the accumulated stock of cars as explanatory variables. The model advanced the state of the art for modeling efforts in this field. It is now, however, out of date.

## SPONSOR

Ford Motor Company
Dearborn, Mich.

## AUTHOR

Daniel B. Suits
University of Michigan
Ann Arbor, Mich. 48109

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to formulate a demand function for automobiles that incorporates consumer credit conditions and the accumulated stock of cars as explanatory variables.

## RELATIONSHIP TO OTHER MODELS

The model bears no direct relationship to other models.

## ASSUMPTIONS

The model assumes that the supply of used cars is a linear function of the sale of new cars. It also assumes that the existing stock of cars is a proper independent variable, and that the change in income level is not a necessary independent variable.

## VALIDATION

The author reports close agreement between actual and calculated demand for the estimation period. The model also predicts a sales level in 1957 of about 6.0 million, compared with a preliminary actual estimate of 6.1 million.

## LIMITATIONS AND BENEFITS

The model is considerably out of date and has been superseded by later models. It does not consider the effects of gasoline price or fuel efficiency regulations on new car demand.

## STRUCTURE

The model consists of a four-equation system explaining the demand for and supply of new and used cars. Three of the equations are combined to obtain an expression for the demand for new cars, the influence of the used car market being implicitly taken into account. The equation is then estimated in first difference form using ordinary least squares. The result for the period 1929-1941, 1949-1956 follows:

$$\Delta R = .115 + \underset{(.011)}{.106}\,(\Delta Y) - \underset{(.088)}{.234}\,\left(\Delta \frac{P}{M}\right) - \underset{(.086)}{.507}\,(\Delta S) - \underset{(.261)}{.827}\,(\Delta X)$$

where standard errors are in parentheses, and

R = retail sales of new cars

Y = real disposable income

P = real retail price of new cars

M = average credit terms, in months

S = stock of used cars

X = dummy variable for 1941 and 1952

## MODEL CONSTRUCTION

This model was calibrated using historical data from 1929-1956. These are listed in the model report. Data sources are also indicated.

## DATA USED IN RUNNING MODEL

Assumptions about the future values of independent variables must be made, and the model can be extended beyond 1956 with actual data.

58-033

DOCUMENTATION

Daniel B. Suits, "The Demand for New Automobiles in the United States 1929-1956," Review of Economics and Statistics, Vol. 39, November 1958.

# A MODEL OF THE AUTOMOBILE INDUSTRY RESPONSE TO GOVERNMENT REGULATIONS

A Model of the Automobile Industry Response to Government Regulations (Pugh-Roberts Model) was prepared by Pugh-Roberts Associates, Inc. for the U.S. Department of Tranportation, Transportation Systems Center (TSC) in 1977. The model was developed for the purpose of forecasting and analyzing the behavior of the automobile industry in a variety of policy and economic situations.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

Kenneth G. Cooper, James M. Lyneis, and
Alexander L. Pugh III
Pugh-Roberts Associates, Inc.
5 Lee Street
Cambridge, Mass. 02139

## MODEL TYPE

Pricing, industrial financial performance, automobile demand, market share, scrappage

## OBJECTIVE OF MODEL

The model forecasts, by computer simulation, the consequences of changing economic conditions, and fuel efficiency, emission, and safety regulations on the four major U.S. automobile manufacturers and on the manufacturers of imported cars. Simulating these effects in terms of profitability, market share, capital investment required, and the prices and features of automobiles sold, the model forecasts (1) industry decisions on product strategies, (2) the likelihood that each manufacturer would meet the mandate under various regulatory conditions, and (3) the financial effects of the industry's attempts to comply with government regulation. The results of these industry decisions are then used to simulate consumer decisions regarding the purchase and use of automobiles.

## RELATIONSHIP TO OTHER MODELS

The model has no direct relationship to other models.

## HISTORICAL BACKGROUND

The model was developed as a part of the Transportation Energy Policies Project at TSC. It complements two ongoing automobile industry investigations at TSC, the Transportation Energy Efficiency Program (TEEP), and the Automobile Fuel Economy Regulatory (AFER) Program.

## VALIDATION

The model report notes that for 1970-76 the actual variable values are simulated with "reasonable accuracy."

## STRUCTURE

The model consists of a simulation of the behavior of consumers and firms in the automobile industry. The consumer sector simulates demand for new cars by size and manufacturer. The industry sector simulates production capacity, selection of new car features, price, management concerns, production costs, and investment costs. The model includes several thousand variables. The exogenous values are set at 1970 actual values at the beginning of the simulation. The production capacity equation, which follows, is representative of equations in the model.

$$LL = NLL \times ETA \times ECPI \times ECRE$$

where:

LL = line life (years)

NLL = normal line life (years)

ETA = effect of technological adequacy

ECPI = effect of concern for product image

ECRE = effect of concern for return on equity

Values are assumed for ETA, ECPI, and ECRE and were subjectively derived through interviews, published reports, assembled data, and other sources of technical expertise at TSC.

## MODEL CONSTRUCTION

The model is a series of algebraic relationships. It requires 1970 values for all exogenous variables, as well as time series of variables representing government regulations and national economic conditions. Some of these variable values are apparently available only from Pugh-Roberts.

## DATA USED IN RUNNING MODEL

Assumptions about the future values of household disposable income, number of households, inflation, and gasoline price are necessary, as are assumptions about future government regulations on fuel efficiency, safety, and emissions, and about future corporate performance goals.

## DOCUMENTATION

K.G. Cooper, J.M. Lyneis, and A.L. Pugh III, A Model of the Automobile Industry Response to Government Regulations, prepared by Pugh-Roberts Associates, Inc. under contract No. DOT-TSC-1183 for TSC, January 31, 1977.

## COMPUTER REQUIREMENTS

The model is quite large and is programmed in the computer language DYNAMO, a non-standard computer language. Documentation of this language appears in Alexander L. Pugh III, Dynamo Users Manual, MIT Press, Cambridge, Mass., 1976.

75-036

## TRANS (TRANSPORTATION RESOURCE ALLOCATION STUDY) - URBAN MODEL

The Transportation Resource Allocation Study Urban Model, commonly referred to as the TRANS-Urban Model, evolved over several years prior to 1975. It was developed by the Department of Transportation for the purpose of assessing national urban transportation policy alternatives. It was used in the 1974 National Transportation Study to assess the effects of alternative funding and pricing policies for the nation's sixty-four largest urbanized areas.

### SPONSOR

U.S. Department of Transportation
Washington, D.C.

### AUTHOR

Edward Weiner
U.S. Department of Transportation
Office of Transportation Planning Analysis
Office of the Secretary
400 Seventh Street, S.W.
Washington, D.C. 20590

### MODEL TYPE

Vehicle miles traveled, modal split, vehicle user costs, accidents, emissions, fuel consumption

### OBJECTIVE OF MODEL

The objective of the model is to assess national urban transportation policy alternatives relating to both highways and transit. It may be used to evaluate the implications of four general types of alternatives: proportions of highway and transit investment, level of total investment, peak-hour parking rates and transit fares, and automobile occupancy rates.

### RELATIONSHIP TO OTHER MODELS

There is no relationship to other models except earlier versions of the TRANS model from which the current model evolved.

### HISTORICAL BACKGROUND

Earlier versions of the TRANS model were highway-oriented and primarily concerned with treating highway investment tradeoffs under varying transit usage assumptions. The latest version is multi-modal and contains an energy module.

## ASSUMPTIONS

Several variables were held constant over the analysis period for which the model was used. These include fatality rates, gasoline consumption rates, residential and business dislocation rates, and capital and operating costs.

## VALIDATION

The model was run for five alternative transportation programs for the 19-year period 1972-1990.

## LIMITATIONS AND BENEFITS

The model's author reports that the model is useful in analyzing alternative urban transportation programs and policies on a nationwide level. The model results, however, represent area-wide averages, and no attempt was made to determine how the results vary within urban areas.

## STRUCTURE

The TRANS-Urban Model System is a set of analytical procedures for evaluting alternative levels and mixes of transportation investments in urbanized areas. It operates at an aggregate level, treating each urban area as a basic unit of analysis. The model input is a specification of a level of investment. Travel projections are made as a function of socio-economic variables and the transportation system supply alternative. Travel is distributed by mode and time of day, with system-performance measures estimated on the basis of the interaction between supply and demand. User effects (such as changes in travel time) are calculated for each mode, along with such external effects as fatalities, dislocations, air pollution emissions, and gasoline consumption.

The output of the model includes the resulting level of highway and transit facilities, travel demand by mode, system performance, and external impacts including fatalities, land consumed, air pollution, dislocation, and energy consumed.

## MODEL CONSTRUCTION

The data used to build the model included, among other data, output from micro-level modal split simulations using a hypothetical urbanized region of 2.5 million persons and a generalized micro-modal split model developed from actual applications to three real cities.

DATA USED IN RUNNING MODEL

The data necessary to run the model include the level and mix of capital funds for transportation investments among four types of transportation facilities: freeways, surface arterials, conventional bus, and rapid transit (both bus and rail).

DOCUMENTATION

Edward Weiner, "Assessing National Urban Transportation Policy Alternatives," Transportation Research, Vol. 10, pp. 159-178, 1976.

# GASOLINE DEMAND MODEL

The Gasoline Demand Model was prepared in 1974 by the staff of the U.S. Department of Transportation, Transportation Systems Center (TSC) for their internal use. The objective of the model is to estimate the demand for gasoline, using a distributed lag mechanism. It is a submodel of the Integrated TSC Automobile and Gasoline Model, which can be used to provide forecasts of new automobile sales, market share, gasoline use, and overall fleet efficiency.

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## AUTHOR

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## MODEL TYPE

Fuel Consumption

## OBJECTIVE OF MODEL

The objective of the model is to estimate the demand for gasoline, using a distributed lag mechanism.

## RELATIONSHIP TO OTHER MODELS

The model is a submodel of the Integrated TSC Automobile and Gasoline Model, which consists of 74-037A, B, and C.

## HISTORICAL BACKGROUND

The model was developed as part of the research effort prompted by the gasoline shortages during the winter of 1973-74.

## ASSUMPTIONS

The model assumes that a stock adjustment mechanism is appropriate for the gasoline market. Further, it assumes that the same adjustment pattern applies to each state over a twenty-year period.

## VALIDATION

The model report does not discuss the validation of this model.

## STRUCTURE

The model estimates the demand for gasoline, using a linear Koyck distributed lag specification in a cross-section time series analysis from 1952 to 1972. The ordinary least squares of the equation follows.

$$GAS = \underset{(11.68)}{.03064}\,(Y) - \underset{(-7.43)}{131.5}\,(GP) + \underset{(41.6)}{.824}\,(GAS_{-1})$$

$$- \underset{(-3.17)}{8.80}\,(MPGY) + \sum_{i=10}^{58} b_i\,(DUM_i)$$

$R^2 = .99$

where t-statisics are in parentheses, and

GAS = gasoline use per capita

Y = real disposable income per capita

GP = real price of gasoline

MPGY = fleet efficiency variable

$b_i$ = the coefficient of DUM for state i

$DUM_i$ = dummy variable for state i

## MODEL CONSTRUCTION

The model was calibrated using annual data by state for all variables from 1952 to 1972. The model report does not indicate sources, except that gasoline sales data come from the Federal Highway Administration.

## DATA USED IN RUNNING MODEL

The model forecasts gasoline demand for specified assumptions regarding the values of income, gasoline price, and fleet efficiency.

DOCUMENTATION

C. Chamberlain, Policy Options: Gas Tax vs. Gas Rationing and/or Auto Excise Tax, TSC, Working Paper, Report No. WP-SP-U2-65, 1974.

# A PRELIMINARY MODEL OF AUTO CHOICE BY CLASS OF CAR: AGGREGATE STATE DATA

A Preliminary Model of Auto Choice by Class of Car: Aggregate State Data, dated January 1974, was prepared by the U.S. Department of Transportation, Transportation Systems Center (TSC) for internal use. It tests consumer sensitivity to differences in sales tax charges for new cars and gasoline costs, holding income and urbanization constant. It is a submodel of the Integrated Transportation Systems Center (TSC) Automobile and Gasoline Model.

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## AUTHOR

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## MODEL TYPE

Market share

## OBJECTIVE OF MODEL

The model tests consumer sensitivity to differences in sales tax charges for new cars and gasoline costs, holding income and urbanization constant. This preliminary model may be used to analyze the effect on consumer auto selection of an excise tax on fuel inefficient cars.

## RELATIONSHIP TO OTHER MODELS

The model is a submodel of the Integrated TSC Automobile and Gasoline Model, which consists of 74-037A, B, and C.

## HISTORICAL BACKGROUND

It has been found that in Europe there exists a direct relationship between the proportion of small cars and both the level of taxes on large cars and the price of gasoline. This study attempts to examine and quantify these relationships for the U.S.

## ASSUMPTIONS

The model assumes that logit analysis is appropriate for determination of market shares. Since a cross-section formulation is estimated, titling or sales tax rates are used as a proxy to measure price sensitivity. Also, a size classification of cars is assumed, based in part on a price classification. Finally, the sum of market shares is not constrained so that the fitted values will sum to unity.

## VALIDATION

No validation efforts are indicated in the model report.

## LIMITATIONS AND BENEFITS

The tax rate variable introduces only absolute rather than relative price fluctuations into the model. Also, cross-section estimates for one year may be inappropriate for time series forecasts.

## STRUCTURE

The model consists of a logit equation for the market share of each of five classes of cars. Each equation is estimated by ordinary least squares using annual state cross-section data for 1972. The estimated relationship for compacts and subcompacts follows.

$$\log\left(\frac{Ps}{1-Ps}\right) = \underset{(.55)}{-3.52} + \underset{(26.3)}{4.24}\,(X_1) + \underset{(2.44)}{.14}\,(X_2) - \underset{(5.11)}{2.21}\,(X_3) + \underset{(.02)}{.08}\,(X_4)$$

where t-statistics are in parentheses and

$Ps$ = proportion of cars of type s registered in each state

$X_1$ = percent urban population

$X_2$ = initial registration tax rate

$X_3$ = per capita state income

$X_4$ = regular grade gasoline price

The equation was divided by the square root of population as an adjustment for heteroscedasticity.

## MODEL CONSTRUCTION

The model is calibrated using aggregate state data for all variables in 1972. Tax rates by state are included in the model report. Data sources for other variables are not indicated.

## DATA USED IN RUNNING MODEL

The model attempts to measure long-run adjustments to differences across states. To estimate the impact on market share, assumptions are necessary as to future gasoline price and tax changes.

## DOCUMENTATION

C. Chamberlain, A Preliminary Model of Auto Choice by Class of Car: Aggregate State Data, Discussion Paper, Report DP-SP-28, TSC, January 1974.

C. Chamberlain, Policy Options: Gas Tax vs. Gas Rationing and/or Auto Excise Tax, Working Paper, Report No. WP-SP-U2-65, TSC, 1974.

# HIGHWAY FUEL CONSUMPTION MODEL

The Highway Fuel Consumption Model was prepared in 1974 by the United States Department of Transportation, Transportation Systems Center (TSC) for internal use. The objective of the model is to integrate models 74-037A and B through an algorithm that computes the fuel efficiency of the entire automobile fleet. The Integrated Model can be used to forecast new automobile sales, market share, gasoline use, and overall fleet efficiency.

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## MODEL TYPE

Fuel consumption

## OBJECTIVE OF MODEL

The objective of this model is to integrate models 74-037A and B through an algorithm that computes the fuel efficiency of the entire automobile fleet.

## RELATIONSHIP TO OTHER MODELS

The model is a submodel of the Integrated TSC Automobile and Gasoline Model, which consists of 74-037A, B, and C.

## HISTORICAL BACKGROUND

The model was developed as part of the research effort prompted by the gasoline shortages during the winter of 1973-74.

ASSUMPTIONS

This model assumes an annual increase of 2.6% per year in vehicle miles traveled.

VALIDATION

No validation efforts are indicated in this model report.

LIMITATIONS AND BENEFITS

The integrated model assumes that the submodels, developed independently, are consistent. The integrated model does not determine vehicle miles traveled, and the level of new car sales is determined only from the market shares model.

STRUCTURE

This submodel consists of an algorithm which joins the market share and gasoline submodels. It computes the fuel efficiency of the entire automobile fleet and estimates the sensitivity of total fuel consumption to changes in the fuel economies of new cars introduced into the vehicle population and to the effects of the existing inventory of vehicles. The entire model thus forecasts new car sales, gasoline use, and overall fleet efficiency annually up to 1980. This fleet efficiency submodel produces input for the gasoline demand submodel.

MODEL CONSTRUCTION

The model is constructed using historical values of:

1) the distribution of the vehicle population in the initial year by fuel economy category and age,

2) the vehicle miles driven per year as a function of vehicle age,

3) survival functions of the vehicles by age, and

4) the projected fractional mix, by fuel categories, of new cars during each projected year.

DATA USED IN RUNNING MODEL

The integrated model requires forecasts of the future values of independent variables, including gasoline price, inflation, and real disposable income, in addition to input from the new car sales submodel. Vehicle miles traveled are assumed to increase at 2.6% per year.

DOCUMENTATION

C. Chamberlain, _Policy Options: Gas Tax vs. Gas Rationing and/or Auto Excise Tax_, TSC, Working Paper, Report No. WP-SP-U2-65, 1974.

# MARKET SHARE MODEL

The Market Share Model was prepared in 1974 by the U.S. Department of Transportation, Transportation Systems Center (TSC). Its purpose is to predict the market share of six classes of automobiles. It is a working model and viewed by TSC as being developmental.

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## AUTHOR

Robert Schuessler and Rene Smith
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## MODEL TYPE

Market share

## OBJECTIVE OF MODEL

The objective of the model is to predict the market share of six classes of automobiles: subcompacts, compacts, intermediates, standards, high-price standards, and luxury models.

## RELATIONSHIP TO OTHER MODELS

An earlier version of the market share model was developed by Charlotte Chamberlain of TSC.

## HISTORICAL BACKGROUND

Model development was undertaken by TSC to improve their earlier version of the model.

## ASSUMPTIONS

It is assumed that consumers are sensitive not to the price of gasoline per se, but to the cost of driving, which is the product of fuel price and fuel efficiency, and that potential new car buyers view a dollar of cost the same, whether it is for base auto price or for titling charges.

## VALIDATION

The model was run for 1974, and the results compared reasonably with observed market shares.

## STRUCTURE

The following equation represents the Market Share Model for the standard size class of vehicles:

$$\log[\text{Standards}/(\text{Total Sales} - \text{Standards})] = 1.37\ (\text{Rate})$$
$$- 9.37 \times 10^{-5}\ (\text{PCPY}) - .023\ (\text{PGAS}) + .886\ (\text{ENC}) + .126\ (\text{WNC})$$
$$- .091\ (\text{ESC}) - .036\ (\text{WSC}) - .631\ (\text{Pacific}) - .388\ (\text{Mountain})$$
$$- .240\ (\text{S. Atlantic}) - .163\ (\text{Mid Atlantic}) - .332\ (\text{New England})$$

where:

Rate = rate of initial registration and sales taxes

PCPY = per capita personal income

PGAS = reported pump price of gasoline

ENC, WNC, etc. = dummy variables for census regions

Other equations were prepared for the six other size classes, but the estimated equations were not presented in the report on the model. Model output includes the percent of new car sales of each of the six types of vehicles.

## MODEL CONSTRUCTION

The model was calibrated on 1972 cross-sectional (state) data for registrations and economic factors. The sum of shares is constrained to 100% by an ex-post normalization.

## DATA USED IN RUNNING MODEL

Future values of the independent variables are required to run the model.

DOCUMENTATION

R. Schuessler and R. Smith, Working Models of Fuel Consumption, Emissions, and Safety Related to Auto Usage and Purchasing Behavior, TSC, Working Paper, WP-230-U2-52, November 1974, subject to change. Paper, WP-230-U2-52, November 1974, subject to change.

# AGGREGATE SALES MODEL

The Aggregate Sales Model was developed in 1974 by the Transportation Systems Center (TSC). Its purpose is to forecast aggregate new car sales, and it is viewed by TSC as being a working model.

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## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to forecast aggregate new car sales.

## RELATIONSHIP TO OTHER MODELS

There is no apparent relationship to other models.

## LIMITATIONS AND BENEFITS

Prior work in this field was insensitive to fuel efficiency. The authors suggest two possible directions for future work. First, the use of quarterly data and a more recent time period would minimize the problems of changing behavioral parameters over time. Second, extracting the fuel cost elasticity from a cross-sectional estimation of the model might eliminate the problem of trend correlation in the data series.

## STRUCTURE

The model is a state-of-the-art stock adjustment model. The estimated equation is:

$$NCR = \underset{(2.07)}{11378.1} + \underset{(7.49)}{.0462}\,(PCE) - \underset{(-6.22)}{.40372}\,(K_{-1})$$

$$- \underset{(-.62)}{69030}\,[PGAS(adjusted)] - \underset{(-1.66)}{4091.31}\,(PCAR)$$

$$- \underset{(-5.67)}{505.477}\,(V) + \underset{(1.62)}{144.373}\,(U_{-1})$$

$$- \underset{(-6.22)}{2864.72}\,(KWAR)$$

$\bar{R}^2 = .9713$ DW = 2.01

where:

NCR = new car registraions (thousands)

PGAS(adjusted) = real cost of driving one mile in a sales-weighted "average" new car (price of gas/average gallons per mile)

PCE = personal consumption expenditures (1967 dollars)

PCAR = CPI for new cars/CPI

U = unemployment rate

$U_{-1}$ = unemployment rate lagged one year

KWAR = dummy variable for Korean War period

$K_{-1}$ = stock of automobiles in new car equivalents at end of previous year

$$K_{-1} = \sum_{1}^{16} NCR_{-i} \times (\text{survival factor})_i \times (\text{depreciation factor})_i$$

where:

$(\text{survival factor})_i$ = historically observed survival rate of cars of age i

$(\text{depreciation factor})_i$ = factor which depreciates vehicles at rate of 25% per year (exponentially)

## MODEL CONSTRUCTION

The data used to build the model were from the period 1950 to 1973. The gas price was adjusted for estimated fuel efficiency changes over the estimation period.

## DATA USED IN RUNNING MODEL

Estimates of forecasts of future values of the independent variables are needed to run the model.

## DOCUMENTATION

R. Schuessler and R. Smith, Working Models of Fuel Consumption, Emissions, and Safety Related to Auto Usage and Purchasing Behavior, TSC, Working Paper, W.P. 230-U2-52, subject to change, November 1974.

# VEHICLE-MILES MODEL

The Vehicle-Miles Model was developed in 1974 at the Transportation Systems Center (TSC). Its purpose is to forecast nationwide vehicle miles of travel. It is viewed by TSC as a working model.

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## AUTHOR

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## MODEL TYPE

Vehicle miles traveled

## OBJECTIVE OF MODEL

The objective of the model is to forecast nationwide vehicle miles of travel (VMT).

## RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

## VALIDATION

The model has been run for 1974.

## LIMITATIONS AND BENEFITS

The authors report that the model does not account for fuel efficiency changes. This is less of a problem in this model, however, than in some others since the durable nature of automobiles tends to dampen changes in efficiency from year to year, and because not only new cars but also existing cars in the fleet are included in the model.

STRUCTURE

Three equations were estimated for VMT using three different 1974 estimates: 1% increase in VMT over 1973, a 1% decrease, and no change. The three equations are, respectively:

$$VMT = -56246 + 7.02\ (Cars) - 1.09\times10^{5}\ (PGAS) + 1.96\times10^{8}\ (RDPY/POP)$$

$$VMT = 34918 + 6.98\ (Cars) - 1.78\times10^{5}\ (PGAS) + 1.87\times10^{8}\ (RDPY/POP)$$

$$VMT = -10664 + 7.00\ (Cars) - 1.43\times10^{5}\ (PGAS) + 1.91\times10^{8}\ (RDPY/POP)$$

where:

VMT = total vehicle miles traveled

Cars = number of cars in the fleet estimated from sales data and expected scrappage

PGAS = (CPI for gas)/CPI

RDPY/POP = per capita real personal disposable income

MODEL CONSTRUCTION

To estimate the equations, 20 years of Federal Highway Administration data through 1974 were used. Three equations were estimated using different values for the 1974 VMT. These 1974 estimates were a 1% increase in total VMT over 1973, a 1% decrease, and no change. The reasons for this were (1) when the data series through 1973 was used, the 1974 forecast was far too sensitive to gas price, and (2) the model was developed when only preliminary 1974 counts were available.

DATA USED IN RUNNING MODEL

Future values of the independent variables are necessary to run the model.

DOCUMENTATION

R. Schuessler and R. Smith, <u>Working Models of Fuel Consumption, Emissions, and Safety Related to Auto Usage and Purchasing Behavior</u>, TSC, Working Paper, WP-230-U2-52, subject to change, November 1974.

73-040

# QUARTERLY DEMAND FOR GASOLINE MODEL

The Quarterly Demand for Gasoline Model was prepared in 1973 by Data Resources, Inc. and was sponsored by the Environmental Protection Agency and the Council on Environmental Quality. Its purpose is to forecast short-term quarterly demand for gasoline. This has been estimated by using four separate sets of historical gasoline consumption data.

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## AUTHOR

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## MODEL TYPE

Fuel consumption

## OBJECTIVE OF MODEL

The objective of the model is to calculate how the demand for gasoline will respond to alternative levels of prices and incomes for two years into the future.

## RELATIONSHIP TO OTHER MODELS

The model may be used in conjunction with the Data Resources, Inc. (DRI) macroeconomic model of the U.S. economy.

## VALIDATION

The model was run for 1972 through the third quarter of 1975. The results indicate clearly the possibility for substantial reduction in the consumption of gasoline as a result of tax or price changes. The model over-predicted gasoline consumption in those areas of the country where there was great discussion of the gasoline shortage during the spring of 1973.

## LIMITATIONS AND BENEFITS

The authors state that the best way to approach the estimation of the demand for gasoline is first to examine the demand for the use of motor vehicles and from that to estimate the demand for gasoline. The data required to perform this analysis were not available, however, and therefore, the authors estimated a direct rather than derived demand function.

The model was estimated in 1973, before the energy crisis, and indicates that reductions in gasoline consumption would result from price increases. However, it is known that the demand for gasoline is relatively price inelastic.

## STRUCTURE

An econometric model of the quarterly demand for gasoline was estimated by the error components technique, using four sets of gasoline consumption data. The one equation presented here was estimated by using Federal Highway Administration highway gasoline data.

$$q_t = .886 - .151\,(P_{t-1}) - .129\,(P_t - P_{t-1})$$
$$+ .452\,(Y_{t-1}) + .435\,(Y_t - Y_{t-1}) + .555\,(q_{t-1})$$

$R^2 = .92$

where:

q = quantity

P = price

Y = income

## MODEL CONSTRUCTION

Four fuel consumption data bases were used to estimate four separate equations of the form above. These were API (American Petroleum Institute) gasoline, API motor gasoline, FHWA motor fuel, and FHWA highway gasoline. Price data from Platt's Oil Price Service were used and modified by a national deflator. Income data were per capita personal income data from the Regional Economics Division of the Bureau of Economic Analysis, U.S. Department of Commerce, and were deflated by the rate of aggregate national personal income to national disposable personal income.

## DATA USED IN RUNNING MODEL

Future values of the independent variables are necessary to run the model. These include lagged gasoline consumption, lagged income, lagged price of gasoline, change in income, and change in the price of gasoline.

DOCUMENTATION

Data Resources, Inc., A Study of the Quarterly Demand for Gasoline and Impacts of Alternative Gasoline Taxes, prepared for the Environmental Protection Agency and the Council on Environmental Quality, December 1973.

Philip K. Verleger Jr. and Dennis P. Sheehan, "A Study of the Demand for Gasoline," in Dale W. Jorgenson, ed., Econometric Studies of U.S. Energy Policy, Data Resources Series Vol. 1, Amsterdam: North Holland Publishing Co., 1976.

# AN ANNUAL MODEL OF PASSENGER CAR GAS CONSUMPTION IN THE U.S.

An Annual Model of Passenger Car Gas Consumption was written in 1973 at the U.S. Department of Transportation, Transportation Systems Center (TSC). It is a working level model and has been superseded.

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## MODEL TYPE

Fuel consumption

## OBJECTIVE OF MODEL

The objective of the model is to quantify consumer sensitivity to gasoline price changes so as to be able to predict the impacts of policy initiatives such as gasoline excise taxes.

## RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

## HISTORICAL BACKGROUND

The author reviewed two existing gasoline consumption models, by Houthakker and Verleger (H-V) and by Fields of the FHWA. Since neither of these were appropriate for the policy-related needs of TSC, this alternate model was developed.

## ASSUMPTIONS

Gasoline demand is influenced by the price of gas only indirectly through the demand for automobiles. The price of gasoline affects new auto purchases, but gas consumption among auto owners is highly insensitive to gas price changes. Consumer demand for gasoline is not a demand for a final product, but rather is a factor of production in the output of vehicle travel. Thus firm factor demand theory rather than consumer choice theory is used in modeling gasoline demand here.

## VALIDATION

The model was run for 1973 through 1975 to predict future gasoline consumption, given varying rates of price inflation, real income rise, and gasoline price rise. The results showed that a large price rise will decrease the growth of gasoline demand to reverse its current trend. A large excise tax on gasoline in a normal economy will have a small negative impact (1.1% per year) on the rate of growth of gasoline demand, while in an economy in an economic downturn with high inflation, the decrease in the demand for gasoline would be 4.7% per year.

## LIMITATIONS AND BENEFITS

Not all coefficients are significant at the 10% level. The author of the model felt that long-run use of it was unjustified because the long-run price elasticities implied in the model were unreliable for large price increases.

## STRUCTURE

The estimated model equation is:

$$\begin{aligned} PCGAS = \; & \underset{(6.8574)}{1.83914\times 10^{5}} - \underset{(-7.04209)}{11815.8}\,(MPGY) + \underset{(10.0751)}{72.2815}\,(Y) \\ & - \underset{(-1.74947)}{1.141\times 10^{7}}\,(RPGY/CPI) + \underset{(1.00616)}{.10727}\,[PCGAS(-1)] \\ & - \underset{(-0.86897)}{2861.94}\,(PCARA/CPI) \end{aligned}$$

where t-statistics are in parentheses, and

PCGAS = motor fuel consumption, millions of gallons

CPI = consumer price index (1958 = 100)

MPGY = average miles per gallon of U.S. passenger cars

PCARA = index of new car prices

RPGY = retail price of gas (excluding taxes)

Y = real personal disposable income (1958 dollars)

MODEL CONSTRUCTION

The model was calibrated using data as follows: The variables motor fuel consumption and average miles per gallon of U.S. passenger cars were taken from the Statistical Abstracts of the U.S. The consumer price index and the index of new car prices were from the Survey of Current Business. Real disposable income was taken from the Federal Reserve Bulletin. The retail price of gasoline excluding taxes is the average price of regular gasoline in 55 cities and is from the Survey of Current Business.

DATA USED IN RUNNING MODEL

Estimated or forecast future values of the independent variables are necessary to run the model.

DOCUMENTATION

Charlotte Chamberlain, Models of Gasoline Demand, TSC, Draft, Report No. RP-SP-21, subject to change, October 1973.

73-043

# U.S. BUS AND TRUCK POPULATION MODEL

The U.S. Bus and Truck Population Model was prepared as part of a master's thesis submitted to Michigan Technological University in 1973. It evaluates the immediate and long-range effects of federally imposed emission standards on trucks and buses. The model estimates the present and future contribution of trucks and buses to total air pollution.

## AUTHOR

Daniel S. Tingley
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## MODEL TYPE

Trucks, emissions, fuel consumption, vehicle miles traveled (VMT), scrappage

## OBJECTIVE OF MODEL

The objective of the model is to evaluate the immediate and long-range effects of federally imposed emission standards on trucks and buses. The model estimates the present and future contribution of trucks and buses to total air pollution.

## RELATIONSHIP TO OTHER MODELS

The model has no direct relationship to other models.

## HISTORICAL BACKGROUND

The model was developed because of the prospective introduction in 1973 of emission standards for trucks and buses similar to those for automobiles.

## ASSUMPTIONS

The model assumes that vehicle model year corresponds with the calendar year.

## VALIDATION

The author reports that model output matches well with historical data for the period 1958-70. Sensitivity analysis for various input parameters indicated, for example, that in 1990 the high projection of total factory sales, which exceeds the median projection by 42%, produces a 30% differential in vehicle population and 28% differential in nitrogen dioxide emissions.

## LIMITATIONS AND BENEFITS

The model emphasizes that truck and bus emissions are a significant component of the total emission level. The model outputs are rather sensitive to projected future sales levels. Economic factors do not enter the causal relationships of the model.

## STRUCTURE

The model consists of a series of submodels for factory sales, scrappage, mileage, fuel usage, vehicle population, and air pollution. In the sales submodel, historical sales data are plotted by weight class of truck for the years 1932-1970. Projections are then made for total sales and sales by class annually to the year 2000. These projections are derived from a 1963 study of America's future resource requirements and availabilities and on the basis of communications with two major truck manufacturers. Sales figures, combined with the calculated scrappage, yield total truck and bus population annually to the year 2000. Mileage per year per vehicle is estimated by class and age, and combined with estimates of average miles per gallon to yield annual fuel consumption. Finally, air pollution estimates are obtained for various average emission rates. Some projections used in this report are plotted on graphs, while others are simply listed by year.

## MODEL CONSTRUCTION

The model is calibrated using historical data on scrappage rates, total factory sales, age distribution of the vehicle population, new vehicle average miles per year, average miles per gallon, and average emission rates for various pollutants. The report includes necessary data values.

## DATA USED IN RUNNING MODEL

The model requires projections of the annual values of all input variables.

## DOCUMENTATION

Daniel S. Tingley, "The Formulation and Development of a United States Truck and Bus Population Model with an Analysis of the Fuel Usage and Air Pollution Contributions," master's thesis submitted to Michigan Technological University, 1973.

COMPUTER REQUIREMENTS

The computer model was written in FORTRAN for use on Michigan Technological University's IBM 360/44 computer. A program list is included in the model report.

# WHARTON E.F.A. AUTOMOBILE DEMAND MODEL

The Wharton E.F.A. Automobile Demand Model, commonly known as the Wharton model, is perhaps the most complex econometric model of long-run automobile demand being used today. The Department of Transportation has used the model for policy analysis, as have the Council of Economic Advisors, the White House, the Department of Energy, the Congressional Research Service, the International Trade Commission, the Office of Technology Assessment, and the Environmental Protection Agency. The model was designed to study the effects on the long-run size and composition of U.S. automobile demand and stock, given various policy proposals and alternative socio-economic futures. In particular, the model may be used to evaluate the effects of twelve categories of automobile taxes, eighteen economic variables that affect the automobile market, and fifteen separate demographic trends.

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## AUTHOR

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## MODEL TYPE

Automobile demand, scrappage, market shares, vehicle miles traveled, pricing

## OBJECTIVE OF MODEL

The objective of the model is to study the impact of altered assumptions concerning such factors as the efficiency and weight of new cars, gasoline prices, and automobile-related tax laws on the long-run size and composition of U.S. automobile demand and stock, through the year 2000.

## RELATIONSHIP TO OTHER MODELS

This model is self-contained.

## ASSUMPTIONS

As with any large model, many assumptions were made in constructing the model. Therefore, only the major assumptions are presented here.

The predictions of the size and composition of automobile demand (sales) and total stock depend on the predictions of the desired variables: desired stock and desired stock shares. (A "desired" level is the long-run, steady state or equilibrium level that would exist if all factors, such as demographics, taxes, and the like, which affect automobile demand were held constant.) The importance of the desired variables is discussed below in STRUCTURE.

To estimate the equations for desired stock and desired stock shares, Wharton used 1972 cross-section data by state. The assumption is made in this estimation that the actual stock and stock shares were approximately equal to their desired or "equilibrium" levels in 1972. This assumption is defended in the report with several arguments: the year 1972 was immediately prior to the oil crisis precipitated by the 1973 OPEC boycott; the economy was reasonably stable; pollution controls had yet to have an effect; and smaller domestic cars had been in the market for several years.

To estimate the equations for new car registrations, scrappage, and new car market shares, it was necessary to produce a time-series of the desired variables. This was done by setting the independent variables of the desired equations to their historical values and using the equations to predict the desired time-series. But these equations did not produce a "reasonable" time-series. Thus, Wharton made a series of major assumptions to adjust the historical values of desired stock and shares to more reasonable values. These assumptions were based, as Wharton argues, on the major economic and demographic differences between the year 1972 and earlier years.

## VALIDATION

The Wharton report on the model notes that the model performs very well in matching 1975 and 1976 new car sales--both total and by class--with only minor adjustments needed to align the initial forecasts with the data currently available. There is, however, no numerical analysis of the model's performance in 1975 and 1976 or in any other historical time period in the report.

For an analysis of this model see: Wharton EFA Automobile Demand Model: An Analysis, Highway Safety Research Institute, University of Michigan, currently in preparation.

## LIMITATIONS AND BENEFITS

The model is intended for long-run analysis of automobile demand rather than for precise yearly estimates of the demand.

STRUCTURE

The Wharton auto demand model is a long-run equilibrium, econometric model--that is, it is designed to forecast the long-run equilibrium levels of the size and composition of U.S. automobile demand and stock. It is a very large and complex model containing almost 400 mathematical statements involving about 600 variables. Of its mathematical statements, about three hundred are identities and over eighty are statistically derived.

Although the model is complex, much of the basic theory underlying it is typical of auto demand models which have been constructed over the last 20 years. The central concept underlying the model is that the automobile market operates by a stock adjustment process. Fundamental to the working of a stock adjustment is the assumption that gross expenditure on a commodity such as automobiles, measured in units sold, can be calculated from the difference between a desired stock and the stock already in existence, taking into account the need to replace old stock as it wears out.

The model operates as follows: From the appropriate exogenous input a capitalized cost per mile for each size-class of vehicle is computed. There are five size-classes defined in the model, from subcompacts to luxury cars. The capitalized cost per mile is essentially the present value of all costs associated with the purchase, sale, and operation of a car (a ten-year lifetime and a lifetime mileage of 100,000 is assumed). This variable, along with the ratio of family income to automobile costs, income distribution, and various demographic factors, is used to determine the desired stock values of the five size-classes of vehicles.

The desired shares are used to compute an average capitalized cost per mile. This average, along with income per family, income distribution, various demographic factors, and non-automobile related transportation indicators, is used to determine desired stock per family.

Total desired stock is used to forecast new car sales (based on new car registrations) and scrappage, and the desired shares are used to forecast new car market shares by size-class. A stock adjustment process is used to link the desired levels to the actual levels.

Also included in the model are equations for VMT per family, new and used car prices, used car transactions, and total stock by age.

Several of the key equations of the model are as follows:

Desired Stock

$$\ln(KEND/FM) = \underset{(2.40)}{-1.90959} + \underset{(3.13)}{0.563344}\,[\ln(RDIP4/FM)]$$

$$-\ \underset{(1.92)}{0.100994}\,[\ln(PER15+/(100 - PER15+))] - \underset{(.84)}{0.199527}\,[\ln(CPMTTCAP/PC)]$$

$$+ \underset{(3.07)}{0.421187} [\ln(LD/FM)] - \underset{(1.48)}{0.0536642} [\ln(MTWNA/FM)]$$

$$+ \underset{(1.61)}{0.0990056} (NPMET/100)$$

$\bar{R}^2 = 0.461$ SEE = 0.596

where t-statistics are in parentheses, and

KEND/FM = number of cars in operation at year end over number of family units

RDIP4/FM = permanent family income

PER15+ = percentage of families (excluding unrelated individuals) earning 15,000 dollars or more in 1970 dollars

CPMTTCAP = desired share weighted cost per mile (includes all classes: domestic and foreign)

LD/FM = number of licensed drivers over number of family units

PC = consumer price index, all items

MTWNA/FM = number of persons not using an automobile to travel to work over number of family units

NPMET = percentage of population living in SMSAs

Mid-Size Class Desired Share

$$\ln\left(\frac{SHRM}{1-SHRM}\right) = \underset{(0.39)}{0.211089} - \underset{(4.57)}{1.98095} [\ln(CPMM/T\text{-}M)]$$

$$- \underset{(1.31)}{.161133} [\ln(YDI/FM/CT*Q)] + \underset{(4.73)}{0.785861} [\ln(FM3+4/FM)]$$

$$+ \underset{(4.01)}{0.162809} (DUMNEW) - \underset{(3.65)}{0.125991} (DUMMTN)$$

$\bar{R}^2 = 0.683$ SEE = 0.0779

SHRM = desired share of mid-size cars

CPMM/T-M = cost per mile for mid-size cars over desired share weighted cost per mile for all other classes

YDI/FM/SC*Q = dollar disposable income over number of family units over fixed weighted cost per mile

FM3+4/FM = number of 3 and 4 member families over number of family units

DUMNEW = dummy, = 1.0 for New England states, = 0.0 otherwise

DUMMTN = dummy, = 1.0 for Mountain states, = 0.0 otherwise

New Car Sales

$$\ln\left(\frac{OMVUANR}{OPMVUAYEND(-1) - SCMVUA}\right) =$$

$$+ \underset{(9.90)}{3.79294} \left[\ln\left(\frac{KEND*AY}{OPMVUAYEND(-1) - SCMVUA}\right) - \underset{(2.49)}{0.255190} (DUMAUTOS)\right.$$

$$+ \underset{(8.30)}{6.03907} \left[\ln\left(\frac{RDI/FM}{RDIP4/FM}\right)\right]$$

$$- \underset{(3.45)}{1.26683} \left[\ln\left(\frac{PUTOTNRL}{PUTOTNR(-1)}\right)\right] - \underset{(35.2)}{2.9151}$$

$\bar{R}^2 = 0.864$ SEE = 0.0473 DW = 2.28

OMVUANR = new car registrations

OPMVUAYEND = year-end stock of cars in operation

SCMVUA = total auto scrappage

KEND*AY = desired stock

DUMAUTOS = strike dummy variable

RDI/FM = real disposable income per family

RDIP4/FM = permanent family income

PUTOTNRL = previous year average new car price, sales weighted

PUTOTNR = new car price, average, weighted by previous year sales

Scrappage

$$\ln\left(\frac{SCMVUA - SCMVAGIV}{OPMVUAYEND(-1) + OMVUANR}\right) = \underset{(7.99)}{-6.98289}$$

$$- \underset{(4.50)}{3.82763} \left[\ln\left(\frac{KEND*AY}{OPMVUAYEND(-1) + OMVUANR}\right)\right.$$

$$+ \underset{(5.32)}{2.91080} [\ln(AVAGEO-20)] - \underset{(2.20)}{.145089} \left[\ln\left(\frac{PUOLD}{PSCRAPAV}\right)\right.$$

$$- \underset{(4.33)}{.338149} [\ln(NRUT)] + \sum_{i=0}^{2} a_i \left[\ln\left(\frac{VMT/K}{VMT/K(-1)}\right)_{-i}\right.$$

$$a_0 = \underset{(2.42)}{2.23399}, \quad a_1 = \underset{(3.60)}{4.19538}, \quad a_2 = \underset{(2.86)}{3.45071}$$

$\bar{R}^2 = .923$ SE = .0462 DW = 2.60

SCMVUA = total auto scrappage

SCMVAGIV = given scrappage for cars over 20 years old

OPMVUAYEND = year-end stock of cars in operation

OMVUANR = new car registrations

KEND*AY = desired stock

AVAGE0-20 = average age of stock, vintages 0 through 20

PUOLD = average price of old cars

PSCRAPAV = scrap-metal price

NRUT = unemployment rate

VMT/K = ratio of vehicle miles traveled to mid-year cars in operation

<u>Mid-Size Class Share of New Car Sales</u>

$$\ln\left(\frac{SHRMDNR}{1 - SHRMDNR}\right) = \ln\left(\frac{SHRM{*}A}{1 - SHRM{*}A}\right) - \underset{(0.66)}{0.00198516}$$

$$- \underset{(82.94)}{0.873077} \left[\ln\left(\frac{TMMDK\text{-}SC}{1 - TMMDK\text{-}SC}\right) - \ln\left(\frac{SHRM{*}A}{1 - SHRM{*}A}\right)\right]$$

$\bar{R}^2 = 0.997$ SEE = 0.0101 DW = 1.26

SHRMDNR = share of new registrations, mid-size class

SHRM*A = desired stock share, mid-size class

TMMDK-SC = share of stock, mid-size class, after scrappage, shares adjusted to sum to one

<u>Vehicle Miles Traveled</u>

$$\ln(VMT/FM) = \ln(WTDMVINT/FM) + \underset{(1.19)}{0.418327}$$

$$- \underset{(3.07)}{0.206013} [\ln(PRGAS/AVMPGVINT/PC)]$$

$$+ \underset{(5.99)}{0.118999} [\ln(PER15+/100 - PER15+)] - \underset{(3.42)}{0.467538} [\ln(RDIP4/FM)]$$

$\bar{R}^2 = 0.852$ SEE = .014 DW = 1.662

VMT/FM = vehicle miles traveled per family by car

WTDMVINT/FM = constant (1972) mileage-weighted sum of vehicle miles by vintage

PRGAS = retail gasoline price per gallon including taxes

AVMPGVINT = vintage-weighted average fleet miles per gallon

PC = consumer price index, total, 1972 = 1.0

PER15+ = percentage of families with real incomes of 15,000 dollars or more (1970 dollars)

RDIP4/FM = permanent income per family, weighted sum of current and lagged real disposable family income

MODEL CONSTRUCTION

The data base used to build the model is quite extensive and well-documented in the third volume of the model report.

DATA USED IN RUNNING MODEL

There are about 30 types of input variables which can be categorized into four major groups: economic variables, demographic variables, transportation mode assumptions, and auto characteristics assumptions. Forecasts of most of the economic input variables are obtainable directly from Wharton E.F.A.'s Annual Long-Term Econometric Model. Forecasts of most of the demographic variables are available from the Bureau of the Census. A table of model input is provided below:

A. Economic Activity and Price Assumptions:

1) personal income

2) income tax payments

3) transfer payments

4) unemployment rate

5) employment

6) consumer price indices (including CPIs related to auto operation and maintenance)

7) retail gasoline price (including tax)

8) interest rates

9) auto ownership and operation tax rates by size class

10) domestic auto production cost index

11) foreign auto export price

12) transportation price index

13) scrap metal price index

B. <u>Demographic Assumptions</u>:

1) number of family units

2) family size distribution

3) percent of population living in SMSA's

4) population by region

5) population 20-29 years old

6) number of licensed drivers

C. <u>Transportation Mode Assumptions</u>:

1) growth in urban transit passengers relative to employment

2) growth in urban transit passengers relative to transit travelers to work

3) growth in non-auto, non-transit travelers to work relative to employment

D. <u>Auto Characteristics Assumptions</u>:

1) curb weights for new cars by class

2) engine displacements for new cars by class

3) number of cylinders for new cars by class

4) transmission types for new cars by class

5) MPG efficiency factors for new cars by class

6) urban fraction of vehicle miles traveled

7) used cars price decay parameters

8) ratios class prices to average, domestics

DOCUMENTATION

George R. Schink and Colin J. Loxely, An Analysis of the Automobile Market: Modeling the Long-Run Determinants of Demand for Automobiles, three volumes, Wharton E.F.A. Inc., February 1977.

COMPUTER REQUIREMENTS

The model program is written in FORTRAN and requires over 150 pages of disk storage.

# TRANSPORTATION SAFETY ANALYSIS MODEL (HIGHWAY SUBMODEL)

The Transportation Safety Analysis Model was developed in 1976 by The Center for the Environment and Man, Inc. under the sponsorship of the Transportation Systems Center (TC). Its Highway Submodel expresses highway accident deaths as a function of vehicle miles traveled, and it forecasts highway accident deaths for five classes of highways.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

Hans C. Joksch
The Center for the Environment and Man, Inc.
275 Windsor Street
Hartford, Conn. 06120

## MODEL TYPE

Accidents

## OBJECTIVE OF MODEL

The objective of the model is to forecast highway accident deaths on different types of highways as a function of vehicle miles traveled on those highway types. The highway types are: rural interstate, urban interstate, main rural roads, other rural roads, and urban highways and streets.

## RELATIONSHIP TO OTHER MODELS

The Transportation Safety Analysis Model is composed of three submodels, one for each of the following modes: air, rail, and highway. They are of a similar structure, but not functionally dependent upon each other.

## HISTORICAL BACKGROUND

The model was developed in order to explore the consequences of alternative policy decisions relating to the highway environment. The model presented here is a first-level, or preliminary, model which was developed using existing data and relationshps. A second-level model has been outlined which employs more extensive relationships. However, currently it is not possible to calibrate this second-level model with the existing data.

## ASSUMPTIONS

As good data are not available, the model assumes that deaths per highway mile are strictly a function of vehicle miles traveled and highway type. Also, for forecasting purposes, 1973 highway mileage figures have been held constant until 1990.

## VALIDATION

The model projections for 1974 and 1975 for total motor vehicle deaths were about 5,000 higher than actual occurrences. Two reasons for this suggested by the author are the 1974-1975 recession and the implementation of the 55 mph speed limit.

## LIMITATIONS AND BENEFITS

Because of the paucity of historical data, the model does not present an accurate representation of the real-world situation. The author indicates this and proposes a second-level model.

## STRUCTURE

The model consists of the following single equation:

$$\frac{\text{Deaths}}{HM_{h,s,t}} = VIO_t\ [(TFA[I]_{h,t})\ (A[I]_h) + (TFB[I]_{h,t})\ (B[I]_h)\ (\frac{VMT_{h,s,t}}{HM_{h,s,t}})]$$

where the parameters are defined as follows:

$VIO_t$ = vehicle interaction factor for year t

$A(I)_h$ = regression intercept for highway type h in traffic density range I

$B(I)_h$ = regression slope for highway type h in traffic density range I

$TFA(I)_{h,t}$ = time factor for $A(I)_h$ in year t

$TFB(I)_{h,t}$ = time factor for $B(I)_h$ in year t

$VMT_{h,s,t}$ = vehicle miles traveled (in millions) for highway type h in states s in year t

$HM_{h,s,t}$ = highway mileage for highway type h in state s in year t

## MODEL CONSTRUCTION

Data on fatalities per highway mile by highway type and vehicle miles traveled per highway mile by highway type were used to construct the model.

## DATA USED IN RUNNING MODEL

The model requires forecasts of vehicle miles traveled by road type, state and vehicle type, vehicle population by type (auto, truck, bus), highway mileage by state and road type, and vehicle factors.

## DOCUMENTATION

Hans C. Joksch, Transportation Safety Analysis, The Center for the Environment and Man, prepared for TSC, Final Report, Nov. 1976. This document lists the computer program and specifies the model input requirements.

## COMPUTER REQUIREMENTS

The model is written in FORTRAN.

# AN ANALYSIS OF THE PRIVATE AND COMMERCIAL DEMAND FOR GASOLINE

A model analyzing the private and commercial demand for gasoline, dated February 1974, was prepared at Michigan State University. The model specifies the supply side of the market and can be used to estimate the price elasticities of private and commercial demand for gasoline. These elasticities are used to analyze the effect of changes in the price of gasoline and to predict market-clearing gasoline prices under various conditions.

## AUTHOR

J. Ramsey, R. Rasche, and B. Allen
Department of Economics
Michigan State University
East Lansing, Mich.

## MODEL TYPE

Fuel consumption

## OBJECTIVE OF MODEL

The objective is to estimate the price elasticities of the private and commercial demand for gasoline in a model which specifies the supply side of the market. These elasticities are then used to analyze the effect of changes in the price of gasoline and to predict market-clearing gasoline prices under various conditions.

## RELATIONSHIP TO OTHER MODELS

The model bears no direct relationship to any other models.

## HISTORICAL BACKGROUND

The study was motivated by the apparent necessity in 1973 for a policy choice between gasoline rationing and allowing the price of gasoline to rise to clear the market.

## ASSUMPTIONS

The model assumes that the supply of gasoline depends on the relative prices of all distillates and the total supply of crude oil available. These variables are assumed to be exogenous. Total private demand is assumed to increase in direct proportion to the number of households. The authors assume that the theory underlying the model has been tested elsewhere. The model is static, assuming that equilibrium is achieved in the gasoline market within one year.

## VALIDATION

Using actual data values of the independent variables for 1970 to 1972, the model estimated annual private demand per household for gasoline within one standard error of the actual value, although the actual value consistently exceeded the forecast.

## LIMITATIONS AND BENEFITS

The model does not incorporate changes in automobile fuel efficiency. The equilibrium and supply assumptions may not be appropriate for the post-1973 period. Nevertheless, the demand <u>and</u> supply specification is a useful approach, as is the division of demand into private and commercial sectors.

## STRUCTURE

The structural specification of the model consists of a supply equation, equations for private and commercial demand, and two identities. The two demand equations which follow were estimated by two-stage least squares, using annual observations from 1946 to 1969.

$$\log(Q) = 2.047 - \underset{(-1.82)}{.222}\,(P_g) + \underset{(1.49)}{.117}\,(P_t) - \underset{(4.74)}{4.034}\,(t_p) - \underset{(11.75)}{1.078}\,(y^{-1})$$

$R^2 = .98$ DW = .96

$$\log(Q_c) = 2.12 - \underset{(-2.16)}{1.03}\,(P_{cg}) + \underset{(2.58)}{1.88}\,(P_d) + \underset{(2.20)}{.65}\,(f_c)$$

$R^2 = .89$ DW = 1.91

where t-statistics are in parentheses, and

$Q$ = annual private demand per household for gasoline

$Q_c$ = annual commercial demand for gasoline

$P_g$ = retail price of gasoline deflated by Consumer Price Index (CPI)

$P_t$ = price index of train travel deflated by CPI

$t_p$ = proportion of the population in the 16-24 age group

$y$ = real disposable income per household

$P_{cg}$ = retail price of gasoline deflated by the price index of truck freight rates

$P_d$ = price index of diesel fuel deflated by the price index of truck freight rates

$f_c$ = index of total ton miles demanded of all freight carriers

MODEL CONSTRUCTION

The model is constructed using annual data for all variables from 1946 to 1969. The necessary variables and data sources for them are listed in the Appendix to the model report.

DATA USED IN RUNNING MODEL

The model is used primarily to generate price elasticities. In order to run the model for future periods, forecasts are required for values of all the independent variables. Such forecasts are not included in the model report.

DOCUMENTATION

J. Ramsey, R. Rasche, and B. Allen, "An Analysis of the Private and Commercial Demand for Gasoline," Department of Economics, Michigan State University, February 18, 1974.

# INFREQUENT PURCHASE BEHAVIOR IN A STOCK ADJUSTMENT MODEL

"The Empirical Implications of Infrequent Purchase Behavior in a Stock Adjustment Model" was written by Richard B. Westin and appeared in the American Economic Review in 1975. The objective of the auto demand model is to analyze the infrequent purchase behavior of new car buyers. This new discretionary replacement model is compared with the conventional stock adjustment model, and the policy implications of both are discussed.

## AUTHOR

Richard B. Westin
Scarborough College
University of Toronto

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of this model of auto demand is to test the empirical implications of infrequent purchase behavior. Individual purchasers of new automobiles enter the market at infrequent intervals and are inactive the rest of the time. In this regard, the traditional assumption of the stock adjustment model that replacement demand is equal to depreciation on the existing stock becomes questionable. Many holders of automobiles have no intention of entering the new car market in the near future and, therefore, do not translate their loss of services from their used car stock into effective demand for new cars.

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models.

## HISTORICAL BACKGROUND

This model was developed in connection with the author's doctoral dissertation at the University of Minnesota entitled, "An Echo Theory of Automobile Demand," 1971.

## ASSUMPTIONS

The discretionary replacement model assumes auto demand can be divided into two components: replacement demand and nonreplacement demand. Replacement demand is assumed to depend on the existing stock of cars by vintage and on discretionary variables that affect the timing of normal replacement demand. Nonreplacement demand is assumed to be a function of economic variables such as disposable and permanent income and the relative price of new automobiles.

## VALIDATION

Using historical data, the discretionary replacement model was tested against the conventional stock adjustment model. In general, the *a priori* predictions of the discretionary replacement model are borne out by the data. In particular, the coefficients of the lagged discretionary variables are opposite in sign and approximately equal in magnitude to the coefficients of the current discretionary variables in most of the estimated equations. The coefficients of the lagged stock variables are positive for the newer stock, which is consistent with the theory of the discretionary replacement model.

## LIMITATIONS AND BENEFITS

The estimated results indicate no substantial differences between the explanatory power of the discretionary replacement model and the traditional stock adjustment model.

From a theoretical point of view the discretionary replacement model considers an aspect of consumer durable goods demand that has been generally neglected. The model explicitly takes account of the fact that individual purchasers of durable goods commonly enter the market only at infrequent intervals and are inactive the rest of the time. This implies that the assumption that current replacement demand is equal to current depreciation on the entire existing stock is questionable. Many holders of durables have no intention of entering the market and do not translate the loss of services from their present stock into effective demand for new stock.

## STRUCTURE

The structure of the discretionary replacement model is as follows:

$$N_t = N^*_t + \sum_{i=1}^{T} (a_i - c_i) V_{t-i}$$

$$+ B (D_t - D_{t-1})$$

where:

$N_t$ = number of new cars purchased

$N^*_t$ = nonreplacement demand

$a_i$ = proportion of cars of age i that are replaced with new cars

$c_i$ = coefficient representing the saturation effect of the existing stock on nonreplacement demand

$V_{t-i}$ = number of cars of vintage t-i existing in period t

$D_t$ = discretionary variable

B = coefficient on discretionary variable

## MODEL CONSTRUCTION

The model is constructed using data sources which are documented in the data appendix of the paper. In general, most of the data come from the Survey of Current Business.

## DATA USED IN RUNNING MODEL

Estimated or forecast values for all the independent variables of the model are necessary to generate predictions for auto demand.

## DOCUMENTATION

Richard B. Westin, "Empirical Implications of Infrequent Purchase Behavior in a Stock Adjustment Model," American Economic Review, Vol. 65, No. 3, pp. 384-396.

Richard B. Westin, "An Echo Theory of Auto Demand," Ph.D. thesis submitted at the University of Minnesota, March 1971.

# GASOLINE USE MODEL

The Gasoline Use Model, dated 1975, was prepared by the Urban Institute for the National Science Foundation. The objective of the model is to formulate and estimate a gasoline demand equation. It was used by the author to provide estimates of the price elasticity of demand for gasoline.

## SPONSOR

Research Applied to National Needs (RANN)
National Science Foundation
Washington D.C. 20550

## AUTHOR

Robert G. McGillivray
Urban Institute
Washington, D.C.

## MODEL TYPE

Fuel consumption

## OBJECTIVE OF MODEL

The objective of the model is to formulate and estimate a gasoline demand equation and ultimately to provide estimates of the price elasticity of the demand for gasoline.

## RELATIONSHIP TO OTHER MODELS

The model has no direct relationship to other models. It is a variant of the natural gas model in P. Balestra and M. Nerlove, "Pooling Cross-Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, Vol. 34, No. 3, July 1966, pp. 585-612.

## HISTORICAL BACKGROUND

This model is the outgrowth of a review of previous gasoline demand models, many of which ignore adjustments in ownership, purchase, and use of automobiles.

## ASSUMPTIONS

The model assumes that new automobile purchases, use of the automobile stock, and gasoline price are predetermined.

## VALIDATION

The model was run to forecast gasoline consumption in 1970-1972 using actual values for the independent variables. The author reports that the forecasts are quite close to, though uniformly larger than, the actual values.

## LIMITATIONS AND BENEFITS

The model does not apply to the period from late 1973 to early 1974 because of the extreme shift in the supply of gasoline. The model can be used for future forecasting only with some assumption or forecast from another model as to the level of new car sales.

## STRUCTURE

This econometric model consists of a single equation for gasoline demand which is estimated by ordinary least squares using annual data from 1951 to 1969.

$$G_t = \underset{(-2.99)}{-111.68} - \underset{(-2.99)}{1.79}\,(P_{gt}) + \underset{(7.04)}{818.69}\,(A_t) + \underset{(5.15)}{.32}\,(L_t) + \underset{(12.73)}{.70}\,(G_{t-1})$$

where t-statistics are in parentheses, and

$G_t$ = passenger-car gasoline consumption, per capita, in gallons, in year t

$P_{gt}$ = price of gasoline, deflated, in year t

$A_t$ = new-passenger-car registrations, per capita, in automobiles, in year t

$L_t$ = average gasoline consumption per automobile, in gallons, in year t

## MODEL CONSTRUCTION

The model is estimated using data from 1951 to 1969. Data sources and the actual data values are listed in the model report.

## DATA USED IN RUNNING MODEL

The model requires forecasts of the independent variables (or their actual values) after 1969.

DOCUMENTATION

Robert G. McGillivray, "Gasoline Use By Automobiles," Transportation Research Record No. 561, 1976.

# MODELING THE RESPONSE OF THE DOMESTIC AUTOMOBILE INDUSTRY TO MANDATES FOR INCREASED FUEL ECONOMY: AN INDUSTRY MODEL

Modeling the Response of the Domestic Automobile Industry to Mandates for Increased Fuel Economy: An Industry Model was written in 1977 by the Rand Corporation under the sponsorship of the National Science Foundation. The purpose of the model is to project the long-run response of the automobile industry to the fuel economy standards mandated by the Energy Policy and Conservation Act of 1975. The model estimates the equilibrium changes in prices, costs, sales, profits, individual and aggregate fuel economies, and governmental revenues when various levels of fuel economy mandates are imposed for 1985.

## SPONSOR

National Science Foundation
Washington, D.C. 20550

## AUTHOR

J.P. Stucker, B.K. Burright, W.E. Mooz
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Automobile demand, fuel economy, pricing

## OBJECTIVE OF MODEL

The purpose of the model is to represent the automobile industry's behavior in response to various fuel economy mandates by the year 1985, assuming that the industry can start its adjustments, plans, and processes today (in 1977). The industry's behavior is modeled in terms of changes in its sales, prices, revenues, fuel economies, costs, and profits.

## HISTORICAL BACKGROUND

This model was developed to analyze the response of the domestic automobile industry to mandates for increased new car fuel economy as legislated in the Energy Policy and Conservation Act of 1975.

## ASSUMPTIONS

The model assumes that the domestic automobile industry acts as if it were a single firm (monopoly assumption) which maximizes its profits by choosing the fuel economy level and number of each type of car it produces and sells. It was calibrated on the assumption that in 1976 the industry was nearly at long-term equilibrium.

## VALIDATION

The model was examined for sensitivity to cost level estimates by testing how the behavior of the industry was affected by changes in the tax rate associated with the fuel economy mandate. It was found that a fine of less than 20 dollars per mpg would cause fuel economy improvements, but not enough to meet the mandated mpg standard.

## LIMITATIONS AND BENEFITS

This is one of a few models developed to analyze the industry's response to the fuel economy mandates. The authors point out two limitations of the model:

1) the model assumes the industry acts as a monopoly and should be replaced with a model that more accurately reflects the oligopolistic nature of the industry; and

2) the parameters of the model are not based on time-series information that reflects the continual dynamic adjustments taking place in the industry's markets.

## STRUCTURE

The model assumes that the domestic automobile industry acts as a single firm that produces and sells three types of cars: large, mid-size, and small. This firm's objective is to maximize the joint profits of its members, as follows:

Maximize Profits: $L = (R-C)\ (1-d) - F$

where:

$L$ = profits

$R$ = total revenue of industry

$C$ = total costs of industry (production and selling)

$d$ = corporate income tax rate

$F$ = total industry fuel economy fine

Revenue, costs, and the fuel economy fine are defined by the following equations:

Revenue: $R = P^bQ^b + P^mQ^m + P^sQ^s$

where:

$P^i$ = new car price of car type i, i = big, mid-size, small

$Q^i$ = new car sales of car type i,

$= \alpha_0^i \, P^{b^{\alpha_1^i}} \, P^{m^{\alpha_2^i}} \, P^{s^{\alpha_3^i}} \, E^{b^{\alpha_4^i}} \, E^{m^{\alpha_5^i}} \, E^{s^{\alpha_6^i}}$

$E^i$ = new car fuel economy of car type i

$\alpha_j^i$ = demand elasticities

Costs: $C = C^b + C^m + C^s$

where:

$C^i$ = industry costs of car type i,

$= B_0^i + (B_1^i + B_2^i \, E^i) \, Q^i$

$B_j^i$ = cost parameter for car type i

Fuel Economy Fine: $F = T \, (M - E) \, Q$

where:

T = fuel economy tax rate

M = fuel economy mandate

Q = total new car sales = $Q^b + Q^m + Q^s$

E = new car fuel economy,

$= Q \left(\frac{Q^b}{E^b} + \frac{Q^m}{E^m} + \frac{Q^s}{E^s}\right)^{-1}$

## MODEL CONSTRUCTION

The model was constructed using 1976 values for the exogenous variables and parameters, which were gathered from these sources:

1) new car sales--Jan. 10, 1977, issue of Automotive News

2) fuel economy values--Environmental Protection Agency estimates

3) price and cost estimates--primarily derived from material released by the Council on Wage and Price Stability

4) demand elasticities--determined based on a review of the recent literature

## DATA USED IN RUNNING MODEL

A tax rate associated with the fuel economy mandate and maximum feasible fuel economy levels for each type of car both need to be specified.

## DOCUMENTATION

D.P. Stucker, B.K. Burright, and W.E. Mooz, Modeling the Response of the Domestic Automobile Industry to Mandates for Increased Fuel Economy: An Industry Model, Rand Corporation, P-5858. December 1977.

# QUANTIFICATION OF TRANSPORTATION NOISE

A model of Quantification of Transportation Noise was prepared in 1975 by Wyle Laboratories for the Motor Vehicle Manufacturers Association. Its purpose is to quantify community noise due to road traffic.

## SPONSOR

Motor Vehicle Manufacturers Association
320 New Center Building
Detroit, Mich. 48202

## AUTHOR

Robert Rackl, Louis Sutherland, and Jack Swing
Wyle Laboratories
El Segundo, Calif. 90245

## MODEL TYPE

Noise pollution

## OBJECTIVE OF MODEL

The objective of the model is to quantify community noise due to road traffic. The objective of the study in which the model was built was to provide supporting information for use in formulating motor vehicle and highway noise policies within an overall national policy of community noise abatement.

## RELATIONSHIP TO OTHER MODELS

There is no relationship to other models.

## ASSUMPTIONS

The model assumes that the adverse responses of human beings to noise can be quantified and that these quantifications are representative of the community. In running the model for cases in the future, various assumptions were made concerning the useful life of the auto fleet, the range of costs for noise countermeasures, the increased vehicle operating costs, etc.

## VALIDATION

The model was evaluated for 1978 and refined on the basis of experiences in Spokane, Washington, whose level of noise was thought to be typical. The model authors feel, therefore, that the results of the analysis conducted for Spokane are applicable to many areas of the country, but caution that there are regional limitations to the applicability.

## STRUCTURE

The model process is as follows:

1) The city or area being analyzed is divided into acoustically homogeneous cells.

2) The noise sources are identified by cell.

3) The level of source activity (e.g., traffic flow) is quantified by time period.

4) The composite total noise exposure for each cell for each time period is quantified, based on noise levels from each source.

5) Transfer functions are applied to the noise exposure level in each cell to produce the percentage of people in the cell who will respond adversely to the noise exposure.

6) Based on the total population of the cell, the number of people who will respond adversely is estimated.

## MODEL CONSTRUCTION

This is a physical systems model in which parameter values are based on actual noise measurements and other current relationships.

## DATA USED IN RUNNING MODEL

Required for each class of vehicles (automobiles, trucks, etc.) are the number of vehicles per unit distance of roadway and a reference noise level measured at a standard distance. In addition, the perpendicular distance of the observer from the roadway must be known.

Other types of data are required and are listed in the model report. These include transfer functions relating noise levels to a human response, population distributions by day and night and land use, and strength of the noise sources.

## DOCUMENTATION

R. Rackl, L. Sutherland, and J. Swing, Community Noise Countermeasures: Cost-Effectiveness Analysis, prepared for the Motor Vehicle Manufacturers Association by Wyle Laboratories, Wyle Research Report

WCR75-2, 2 Volumes, July 1975. Appendices A, B, and C, WCR-76-15, June 1977.

COMPUTER REQUIREMENTS

The program is designed to be run on a large computer with the user at a remote terminal.

# ECONOMETRIC MODELS OF THE DEMAND FOR MOTOR FUEL

Econometric Models of the Demand for Motor Fuel was prepared in April 1975 by the Rand Corporation. The study was sponsored by the National Science Foundation and the Federal Energy Administration. It develops econometric measures of the short-run and long-run demand for highway motor fuel and gasoline.

## SPONSOR

National Science Foundation
Washington, D.C. 20550

Federal Energy Administration
Washington, D.C. 20461

## AUTHOR

Burke K. Burright and John H. Enns
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Fuel consumption, vehicle miles traveled, automobile demand, fuel economy

## OBJECTIVE OF MODEL

The purpose of the study in which the models were prepared was to develop econometric measures of the short-run and long-run demand for highway motor fuel and gasoline.

## RELATIONSHIP TO OTHER MODELS

This study is part of Rand's continuing research program on the evaluation of measures to conserve energy. Other models in the series include 74-001A - Generalized Automobile Design Model, 74-001B - Automobile Fleet Mix Model, and 74-001C - New Car Sales/Auto Ownership/ Vehicle Miles Traveled (NAV) Model. This report expands on work appearing in 74-001B and 74-001C.

## ASSUMPTIONS

The study estimates both the short-run and long-run demand for gasoline under a variety of assumptions as to functional form and relevant variables. The short-run model assumes that the bias of simultaneous equations is not a serious problem; therefore only ordinary and generalized least squares estimation procedures are presented. The theoretical analysis assumes that vehicle miles traveled are produced for each household according to the short-run production function. The model also assumes that all automobiles are alike. The long-run model assumes that new and used cars have the same average fuel efficiency. Real prices of gasoline and new cars are exogenous to the model.

VALIDATION

The models' results are compared and contrasted with the results produced by other models.

LIMITATIONS AND BENEFITS

The study provides a good comparison of various estimates of the elasticity of demand for gasoline. However, the long-run model assumes a perfectly elastic supply of gasoline and new cars, so that market-clearing price-quantities combinations cannot be predicted.

STRUCTURE

The study estimates both the short-run and long-run demand for motor fuel. The short-run demand function is derived from a simple model of household decision-making which explains the demand for vehicle miles traveled. The function is estimated using two data bases: (1) a pooled time-series of state data from 1955 to 1970, and (2) national time-series data from 1950 to 1972. Estimates using the pooled data are obtained by generalized least squares and ordinary least squares (OLS). A representative equation estimated by generalized least squares is:

$$\log(F/POP) = \underset{(-3.5)}{-.66} - \underset{(-11.5)}{.27}\,[\log(P_f)] + \underset{(9.5)}{.18}\,[\log(Y/POP)] + \underset{(42.3)}{.93}\,[\log(A/POP)] - \underset{(1.8)}{.09}\,(UPOP)$$

$\bar{R}^2 = .95$ D.F. = 763

where t-statistics are in parentheses, and

F = fuel consumption

$P_f$ = average real price of regular gasoline

Y = disposable personal income

A = registered vehicles (millions)

UPOP = % of state population residing in urban areas

POP = population

Other equations included a miles-per-gallon variable. Short-run estimates are also obtained using national time-series data for fuel used in automobiles only. A short-run fuel demand function is estimated and combined with an equation explaining miles-per-gallon to obtain short-run fuel demand functions such as the following:

$$\log(F/POP) = 8.337 - .190\,[\log(P_f)] - .810\,[\log(M)]$$
$$+ .190\,[\log(w)] + .010\,[\log(Z)] + .849\,[\log(A/P)] + .42\,(D)$$

where:

M = average auto fuel efficiency (miles per gallon)

Z = unemployment rate (%)

D = dummy variable for safety and emission standard years (1968-72)

The equations are estimated for 1950 to 1972.

The long-run fuel demand model focuses on changes in the total number of automobiles owned. New car sales, the used car stock, and used car price are estimated using both ordinary least squares and two stage least squares for a variety of functional forms. A representative equation, estimated by OLS for 1954 to 1972, appears below.

$$\log(N/DPOP) = \underset{(-51.466)}{-2.931} - \underset{(-5.902)}{1.629}\,[\log(P_n)]$$
$$+ \underset{(2.031)}{.958}\,[\log(P_u)] + \underset{(2.412)}{5.316}\,[\log(Y/H)] + \underset{(3.170)}{.131}\,(ST)$$

$\bar{R}^2 = .67$

where t-statistics are in parentheses, and

N = U.S. new car unit sales

DPOP = driving age population

$P_n$ = average real price of new cars

$P_u$ = average real price of used cars

Y = permanent disposable personal income

H = households

ST = dummy auto strike variable (= -1, strike year; = 1, year following strike; = 0, otherwise)

MODEL CONSTRUCTION

Data sources for the short-run and long-run demand models are listed in the model report. Automobile gasoline use, automobile miles driven, automobile ownership, and average fleet efficiency were taken from Highway Statistics. Automobile registration and production data were obtained from the Federal Highway Administration. The actual data values for all variables are also listed in the report.

DOCUMENTATION

Burke K. Burright and John H. Enns, Econometric Models of the Demand for Motor Fuel, The Rand Corporation, R-1561 - NSF/FEA, April 1975.

# ELASTICITIES OF DEMAND FOR NEW AUTOMOBILES

"The Elasticities of Demand for New Automobiles" was written at the General Motors Corporation Research Laboratories and is dated May 1976. The demand for new automobiles is examined by using single equation models and monthly registration data. The model estimates the impact of income, new car price, used car price, and fuel prices on auto demand. These estimates are selected on the basis of their statistical properties, their potential for forecasting, and the results of ridge regression analysis.

## SPONSOR

General Motors Corporation

## AUTHOR

H. F. Gallasch, Jr.
General Motors Research Laboratories
Warren, Mich. 48090

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to study and estimate the impact of new car price, income, used car price, and gasoline price on auto demand.

## RELATIONSHIP TO OTHER MODELS

No relationship to other operating forecasting models is indicated in the model report.

## HISTORICAL BACKGROUND

The author notes that the majority of automobile demand studies have been primarily concerned with testing various theories of durable goods demand. The Gallasch model was developed to pay more attention to structural parameter estimates such as income, new car price, used car price, and fuel price.

## ASSUMPTIONS

The model assumes that demand depends on income, new car price, used car price, gasoline price, and unemployment. Seasonal dummies are included as right hand variables. Ridge regression estimation was used to test the effect of multicollinearity in the explanatory variables.

## VALIDATION

The parameter estimates are compared with other estimates that have appeared in the economics literature. The elasticities of the Gallasch model compare favorably with other historical elasticities (price and income). It is reported that one estimated equation has an average forecasting error of 14% which is equivalent to 100 thousand units on a monthy basis.

## LIMITATIONS AND BENEFITS

A limitation of the model is that since the model is monthly, its use as a policy analysis tool is rather limited due to the extreme short-run nature of the model. Short-run cyclical factors dominate the model as expected. A benefit is that a fairly innovative estimation technique, ridge regression, is employed.

## STRUCTURE

Single equation models are examined. Both static and dynamic equations are estimated. The equations are all of the form:

$$X = A\ (P_{nc}{}^{\alpha}1)\ (P_{uc}{}^{\alpha}2)\ (P_{g}{}^{\alpha}3)\ (Y^{\alpha}4)$$

$$x \exp[B(U) + \sum_{i=1}^{<12} G_i\ (D_i)]$$

where:

$X$ = new car sales (domestic and imports)

$A$ = constant term

$P_{nc}$ = new car price with coefficient $\alpha_1$

$P_{uc}$ = used car price with coefficient $\alpha_2$

$P_g$ = gasoline price with coefficient $\alpha_3$

$Y$ = disposable income with coefficient $\alpha_4$

$U$ = unemployment rate with coefficient B

$D_u$ = monthly dummy variables with coefficients $G_i$

## MODEL CONSTRUCTION

The model is calibrated using monthly data for 1967-75, including:

1) New car registrations from the Survey of Current Business (Department of Commerce),

2) Consumer Price Index for new cars from the Department of Commerce,

3) Consumer Price Index for used cars from the Department of Commerce,

4) Gasoline price from the Petroleum Publishing Company,

5) Income from the Department of Commerce, and

6) Unemployment rate from the Department of Commerce.

## DATA USED IN RUNNING MODEL

For future projections, forecasts of the independent variables are required. For within-sample validation, the historical data are required.

## DOCUMENTATION

H. F. Gallasch Jr., "Elasticities of Demand for New Automobiles," Research Laboratories, General Motors Corporation, May 21, 1976.

# DECISION ANALYSIS OF AUTO EMISSION CONTROL

A model of Auto Emission Control was prepared in 1976 at Stanford University, with the objective of providing a general analytical framework to examine automobile emissions as a social problem. Specifically, a driver behavior model is used to compare the effects of "direct regulation" policies and "market" policies in correcting the auto emission problem.

## AUTHOR

Bruce R. Judd
Stanford University
Stanford, Calif. 94305

## MODEL TYPE

Emissions, economic impact

## OBJECTIVE OF MODEL

The objective of the model is to evaluate the social costs and benefits of alternative emissions control strategies.

## RELATIONSHIP TO OTHER MODELS

There is no formal, direct relationship to other models. However, much of the data used in Judd's model comes from Dewees' work on automobile air pollution. See, for example, Donald W. Dewees, Economics and Public Policy: The Automobile Pollution Case. Cambridge, Mass., MIT Press, 1974.

## HISTORICAL BACKGROUND

The study was prepared as the author's Ph.D. thesis in Engineering-Economic Systems at Stanford University.

## ASSUMPTIONS

Numerous assumptions are made concerning vehicle type, vehicle size, vehicle age, operating costs, emission control devices, vehicle depreciation, willingness to pay to reduce automotive emissions by 50%, emissions taxes, gasoline taxes, etc. These are outlined in Chapter 4 of the model report.

## VALIDATION

Sensitivity analysis with respect to the parameters of the model was conducted. It is concluded that auto emissions standards are not the most socially beneficial of regulatory alternatives, as compared to gas taxes, emissions taxes, or to no controls.

## LIMITATIONS AND BENEFITS

A limitation of the analysis is that the numbers generated by the model are illustrative and are intended only to produce insight into which factors are most important in choosing among emission control plans. Thus, the model is not meant to be used as a forecasting tool per se. A benefit of the model is that it explicitly deals with issues traditionally not quantified, such as values derived from motoring and the social willingness to pay for eliminating pollution.

## STRUCTURE

There are two main models used in the analysis, a driver model and a breather model. These interact to yield a social profit indicator for each emissions control policy considered. The principal components of the driver model are: demand curve generator, supply curve generator, vehicle evaluation, market trading, new vehicle prices, and driver profit computation. The breather model does not have any submodels.

## MODEL CONSTRUCTION

The model was constructed using data sources which are documented in Appendix A of the model report. The Los Angeles area was used as the subject area for study.

## DATA USED IN RUNNING MODEL

To run the model, projections or assumptions about the data used in the construction of the model are required.

## DOCUMENTATION

Bruce R. Judd, Decision Analysis of Auto Emission Control, doctoral dissertation at Stanford University, Dept. of Engineering-Economic Systems, May 1976.

## COMPUTER REQUIREMENTS

The computer model code, written in FORTRAN, is listed in Appendix C of the dissertation. Appendix D has computer output for years 1976-1980.

# THE MOTOR VEHICLE/HIGHWAY NOISE MODEL

The Motor Vehicle/Highway Noise Model was reported in "A Study of the Magnitude of Transportation Noise Generation and Potential Abatement," a seven-volume report which includes an assessment of transportation-noise-abatement problems and their potential solutions. It was written in 1970 by Serendipity, Inc. under sponsorship of the U.S. Department of Transportation.

## SPONSOR

Department of Transportation
Office of the Secretary
Office of Noise Abatement
Washington, D.C. 20590

## AUTHOR

Serendipity, Inc.
Eastern Operations Division
Suite 701, 2001 Jefferson-Davis Highway
Arlington, Va. 22202

## MODEL TYPE

Noise pollution

## OBJECTIVE OF MODEL

The objective of the Motor Vehicle/Highway Noise Model is to estimate the noise generated as a result of alternative traffic flows and vehicle mixes and to evaluate the effectiveness of noise abatement alternatives.

## RELATIONSHIP TO OTHER MODELS

There is no apparent relationship to other models.

## HISTORICAL BACKGROUND

The model was developed under U.S. Department of Transportation sponsorship as a part of their program to assess noise problems stemming from all modes of transportation.

## ASSUMPTIONS

The model is based on the following simplifying assumptions:

1) The sound source is omni-directional.

2) Sound rays travel in a straight line on the shortest path between predefined points.

3) The phase phenomenon of sound is omitted from consideration.

4) When the air absorption option is used, no extreme conditions of temperature or relative humidity will prevail.

5) Any excess attenuation will occur over a ground strip parallel to the road element.

6) The reflection surfaces are flat and rigid so that no resonance due to barrier vibration occurs.

7) The road element is straight.

8) The direction edge is a straight line.

9) Sufficient accuracy is maintained by separating a continuous sound spectrum into eight octave bands.

10) No sound distortions such as from shielding and focusing occur due to the presence of other highway vehicles.

VALIDATION

No validation of the model was reported in the model report.

STRUCTURE

The model is a generalization of the motor vehicle-highway system which contains the following three elements: noise source, noise paths, and receiver. Primary calculations in the model are performed in the main loop of the computer program which consists of a series of five hierarchical loops. The eight-octave band spectrum values at each of the receiver points from all source points through each designated path are calculated here.

MODEL CONSTRUCTION

The model is based on empirical noise relationships.

DATA USED IN RUNNING MODEL

Inputs to the model include descriptions of the roadbed and adjoining barriers in terms of widths, heights, and placement angles; absorption spectra for road surfaces (optional); noise source spacing (or vehicles per hour per lane); percentages of vehicle types (optional); receiver points; sound ray behavior; sound path; and air absorption and excess attentuation values (optional).

DOCUMENTATION

A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Final Report, Vol. I--Summary, Serendipity, Inc., Report No. OST-ONA-71-1, November 1970. NTIS No. PB-206 067.

A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Final Report, Vol. IV--Motor Vehicle/Highway System Noise, Serendipity, Inc., Report No. OST-ONA-71-1, November 1970. NTIS No. PB-203 185.

COMPUTER REQUIREMENTS

The computer program is written in FORTRAN IV for the Burroughs 5500 computer. The users' manual for the model program is Appendix A of Vol. IV of the report, cited above.

# MODELING THE DEMAND FOR AUTOMOBILES IN THE UNITED STATES

A model of the Demand for Automobiles in the United States was written in 1977 as a dissertation at The University of Michigan. The general objective of the model is to improve upon the typical single-equation models of auto demand by increasing the number of endogenous variables considered (e.g., market segment, new car demand, new car price, and used car price).

## AUTHOR

Michael M. Luckey
The University of Michigan
Ann Arbor, Mich. 48109

## MODEL TYPE

Auto demand, market share, vehicle miles traveled (VMT), pricing

## OBJECTIVE OF MODEL

The objectives of developing this model are as follows:

1) To build an operational forecasting model of automobile demand, or, at the very least, to provide the foundation for a model that could be used in an ex-ante forecasting program.

2) To expand the single-equation models of auto demand typically found in the literature. This includes improving the specification of auto demand per se as well as increasing the number of endogenous variables in the model (e.g., market segment new car demand, new car price, and used car price).

3) To incorporate the following distinguishing features into an integrated demand model:

    a) The change in the supply of unsold new cars is assumed to influence new car demand through its impact on new car price.

    b) The used car market is assumed to affect new car demand through used car prices.

    c) The model determines the composition of new car sales by three basic market segments: domestic small (wheel base under 112"), domestic large (wheel base 112"and over), and imports (foreign-type cars and captive imports; domestics produced in Canada are excluded).

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models.

## HISTORICAL BACKGROUND

The model was developed as the author's doctoral dissertation in Economics at The University of Michigan.

## VALIDATION

Two types of evaluation exercises are reported in the paper. First, the dynamic properties of the new car price equation are analyzed. In particular, it is shown that increases in the retail price of new cars are almost exactly proportional to increases in the wholesale price of new cars in the long run. Second, the forecasting behavior of the new car demand equation is analyzed. Both within-sample and post-sample predictions are considered. The equation performs quite well in the within-sample period (1969.1-1971.4) with a mean absolute percentage error of less than one percent. For the post-sample period (1972.1-1974.4) the predictions of the equations are not as accurate as those from within the sample. However, this is to be expected, based on the econometric methods employed. The root mean squared error for the post-sample period is 560,000 units, which is not completely out of line with the standard error of estimate of 330,000 units.

## LIMITATIONS AND BENEFITS

The limitations of the model are:

1) Although not specifically mentioned in the paper, the inventory equation of the model has a definite tendency to underpredict domestic new car inventory levels. This may be caused by an unfortunate specification of the equation in which inventory levels were assumed to depend on the natural logarithm of domestic new car sales.

2) Most of the equations of the model were fitted with data only through the third quarter of 1973 (the new car price equation is an exception, being fitted through 1974.4). This was done intentionally to avoid having to take into account the disruptive effects of the Arab oil embargo in the specification and estimation of the model. However, it also limits the usefulness of the model for forecasting, since the model does not understand the large increases in automobile operating costs that have occurred since 1973. Thus the model needs to be refitted with more recent data.

The benefits of the model are:

1) The approach to the modeling of the market segments is unique in terms of the public literature. The segments are viewed as an

example of the problem of seemingly unrelated regressions and are specified in such a way that the adding-up problem is avoided. In addition, the market segments display some very interesting dynamic properties with respect to changes in income or the unemployment rate.

2) The model also explains and predicts a number of auto market variables that are generally neglected in models of auto demand (e.g., new car price, used car price, inventories).

STRUCTURE

The model contains nine endogenous variables that are explained in stochastic equations. They are: retail new car price, retail used car price, new car demand, market segment new car demand (domestic small, domestic large and imports), domestic new car inventories, used car stock, and vehicle miles traveled (VMT). In addition, there are two identities that explain total domestic new car demand and total small new car demand.

The change in the supply of unsold new cars is assumed to influence new car sales through its impact on new car price. New car price at the retail level is explained as a function of the wholesale price for new cars and the recent change in inventory levels. This establishes feedback from new car demand to retail price. A loop is created between new car demand, inventories, and retail price. Essentially what has been done is to endogenize new car price. Most auto demand models treat price as exogenous.

The used car market is assumed to affect new car demand through used car prices. An increase in used car prices, other things equal, will lower the net purchase price of a new car and stimulate demand. New car sales, in turn, impact on the stock of used cars held by franchised new car dealers. Finally, used car prices are negatively correlated with the level of the used car stock. Circularity has been established between new car demand, used car stock, and used car prices.

The model determines the composition of new car sales by market segments defined on the basis of length of wheelbase: domestic small (wheelbase under 112"), domestic large (wheelbase 112" and over), and imports (foreign-type cars and captive imports; domestics produced in Canada are excluded).

MODEL CONSTRUCTION

The model was built with quarterly data generally available from the following sources: Survey of Current Business, Wards Automotive Reports, Automotive News, Motor Vehicle Manufacturers Association Statistics Department.

## DATA USED IN RUNNING MODEL

Values for all the exogenous variables are necessary to simulate the model over any time period.

## DOCUMENTATION

Michael M. Luckey, "Modeling the Demand for Automobiles in the United States", in An Overview of Simulation in Highway Transportation, Simulation Councils Proceedings Series, Vol. 7, Number 1, June 1977, pp19-25.

## COMPUTER REQUIREMENTS

The model may be run using the MIST (Michigan Interactive Simulator of Time Series) simulation program at The University of Michigan.

# MANUFACTURING ASSESSMENT SYSTEM

Automotive Data Base for Manufacturing Assessment System was prepared by Rath and Strong, Inc. in 1975 for the U.S. Department of Transportation, Transportation Systems Center. The purpose of the study was to develop a computer based methodology to evaluate the impact on manufacturing resources in the automotive and truck industry of various alternative vehicles and implementation plans. A basic concept employed in the report is to group products and their component resources according to how they are made rather than how they are sold or used.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

L.H. Lindgren and R.G. Fitzgibbons
Rath and Strong, Inc.
Boston, Mass.

## MODEL TYPE

Vehicle manufacturing resource utilization, automobile design, pricing

## OBJECTIVE OF MODEL

The objective of the Manufacturing Assessment System is to develop a computer based methodology and data base capable of analyzing the impact on manufacturing resources of various alternative vehicle designs and configurations.

## RELATIONSHIP TO OTHER MODELS

This model is a part of the DRI Motor Vehicle Assessment System.

## HISTORICAL BACKGROUND

This report expands the National Academy of Sciences/Committee on Motor Vehicle Emissions II data base completed in December 1974. The added data elements include after-market usage and prices, reliability and life cycle maintenance costs and quality costs. Improved structural elements consist of a more detailed component definition of the body and drive system. The model was originally developed for use by the Transportation Systems Center in the Automotive Energy Efficiency

Program (AEEP).

## ASSUMPTIONS

The basic assumption underlying the entire data base and model is that the auto industry can be analyzed by identifying the significant products, components, and supporting resources used in the manufacturing and assembly of vehicles. More specifically, the data base is structured around the concept of how a product is made rather than how it is sold or used. The data base and model attempt to describe and analyze the manufacturing process in the automobile industry.

## LIMITATIONS AND BENEFITS

Much of the data used in the areas of cost and resource utilization are now out of date and subject to considerable change in the future as the auto companies develop new products and manufacturing technologies. This implies that the ability of the model to predict the cost and resource utilization of future vehicle configurations depends on a continual updating of the data.

## STRUCTURE

The Manufacturing Assessment System is composed of the following data bases:

1) <u>Product Data Base</u>, the identification of the end item vehicles and the components.

2) <u>Resource Data Base</u>, the identification of the facilities and tooling required to manufacture the components and assemble the vehicles.

3) <u>Product-Resource Master Data Base</u>, the cross reference or chaining data base to establish the relationship of the products to the proper resource.

4) <u>Configuration and Cost Data Base</u>, the specific data base of the end item vehicle and all the components that comprise the vehicle configuration. The manufacturing costs are included in this data base for use in the development of vehicle sticker prices.

5) <u>Retrieval Number Data Base</u>, the significant part numbering or coding system used in the identification of specific vehicle configurations.

6) <u>Fuel Economy, Emission, Maintenance, Mileage Patterns Data Base</u>, the end item vehicle performance data that is used in the simulation programs for the determination of total operating costs.

## MODEL CONSTRUCTION

The data sources used to build some of the data bases are documented in the model report; however, some are undocumented.

## DOCUMENTATION

L.H. Lindgren and R.G. Fitzgibbons, Automotive Data Base for Manufacturing Assessment System, Rath and Strong, Inc. for DOT/TSC No. 803, June 1975.

# URBAN TRAFFIC CONTROL SYSTEM--PROGRAM 1 SIMULATION MODEL (UTCS-1 MODEL)

The Urban Traffic Control System - Program 1 Simulation Model, dated February 1976, was prepared by Honeywell, Inc. for the Federal Energy Administration and the Federal Highway Administration (FHWA). The purpose of the model is computer simulation testing of traffic control scenarios to determine the effects of various traffic conditions, network configurations and traffic control policies on the consumption of fuel by vehicles in a network. The impact on fuel consumption of one-way streets, a pedestrian scramble system, fixed-time and actuated traffic signals, signal controller cycle lengths, traffic volume levels, and exclusive bus lanes was examined.

## SPONSOR

Federal Energy Administration
Office of Transportation Policy Research
12th and Pennsylvania Avenue, N.W.
Washington, D.C. 20461

U.S. Department of Transportation
Federal Highway Administration
Offices of Research and Development
Washington, D.C. 20590

## AUTHOR

Honeywell Traffic Management Center
Honeywell, Inc.
600 Second Street, N.E.
Hopkins, Minn. 55343

## MODEL TYPE

Fuel economy

## OBJECTIVE OF MODEL

The basic objective of the model is to study the impact on vehicle fuel consumption of various traffic control strategies, including one-way streets, a pedestrian scramble system, fixed-time and actuated traffic signals, signal controller cycle lengths, traffic volume levels, and exclusive bus lanes.

The UTCS-1 model simulates traffic operations on street networks. This model was originally designed to assist in developing traffic control strategies for use on the TCS network in Washington, D.C. It is, however, a general-purpose model, and can be applied to a wide range of networks and traffic conditions.

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models.

## HISTORICAL BACKGROUND

The UTCS-1 simulation model reported here is an in-house FHWA model and was provided to Honeywell by the FHWA. The basic model was not developed by Honeywell, Inc., although they did make the following modifications to the model for use in their research.

1) Rather than storing vehicle trajectories on a mass storage device for later use, trajectories are used at each program time step to compute values for fuel consumption efficiency and emissions for each vehicle.

2) The capability of the program was expanded to permit simulation of up to 160 links, 85 nodes, and 20 actuated intersections.

## ASSUMPTIONS

The following traffic control scenarios were run on the model

1) one-way/two-way streets

2) pedestrian scramble system

3) fully actuated versus pre-timed signal systems

4) comparisons of cycle lengths

5) variations in traffic demand

6) exclusive bus lanes

For each scenario, the specific input assumptions actually used in running the UTCS-1 Model are detailed in Section 3 of the model report.

## VALIDATION

The principal results of the research with respect to each simulation experiment follow. The impact on fuel consumption of each traffic control strategy is stated:

1) <u>One-Way/Two-Way Streets</u>: On average, fuel consumption efficiency (FCE) in vehicle miles per gallon is estimated to increase by 12 percent as a result of changing some two-way streets to one-way streets in the UTCS network in Washington, D.C.

2) <u>Pedestrian Scramble System</u>: The use of a pedestrian scramble system implemented by an all-red interval is estimated to decrease

fuel consumption efficiency (FCE) by 35-48 percent, depending on the level of turning movements in the traffic flow.

3) Fully Actuated vs. Pre-Timed Signals: Fully actuated signals are estimated to increase FCE significantly, based on data for M Street in Washington, D.C. with a main-street/cross-street volume ratio of 7:1. The improvement in FCE was inversely related to the amount of cross-street traffic.

4) Cycle Lengths: FCE is estimated to increase as cycle length is increased.

5) Traffic Demand: The simulation results indicate that FCE in an urban network is inversely related to vehicle traffic demand, as expected.

6) Bus Traffic: The simulation results showed that the addition of bus traffic to an arterial caused a decrease in FCE. The results also indicated that auto traffic is penalized (longer delays, more fuel consumed) by the use of exclusive bus lanes.

STRUCTURE

The UTCS-1 model operates by generating vehicles at the input sources as specified by the input data. The position, speed, and acceleration of each vehicle generated is recorded in the simulation data base. Vehicles move throughout the network according to the rules that drivers observe when on a traffic network; for example, vehicles turn in proportion to the probabilities included for each intersection, and they switch lanes according to demands imposed by congestion and the need to execute turning movements. In addition, urban bus operation, pedestrian interference, and short-term, disruptive events such as taxicab pickups and stalled vehicles can be readily simulated. Regression analysis was performed with which it was determined that fuel consumption efficiency is most highly correlated with average network speed and can be predicted by the equation:

$$FCE = 0.142\ (S) + 3.61$$

where:

FCE = fuel consumption efficiency in miles per gallon

S = average network speed in miles per hour

MODEL CONSTRUCTION

This is a network-based accounting model using traffic generation and directional data collected by the Federal Highway Administration.

## DATA BASE USED IN RUNNING MODEL

Typical input data requirements include description of network geometry, network characteristics, and the signal control strategies. Data inputs must also describe the traffic stream itself, including the volumes of traffic entering or leaving at the periphery of the network and at midblock sources and sinks, and the percentage of turning movements at each intersection in the test network. While not required, the following types of inputs can be applied usefully: the percentage of truck and bus traffic in the network, bus route descriptions, and similar types of information.

## DOCUMENTATION

Honeywell Inc., Fuel Consumption Study. Urban Traffic Control System (UTCS) Software Support Project, prepared for FHWA, Report No. FHWA-RD-76-81, February 1976. NTIS No. PB-259 003.

A summary description of UTCS-1 simulation model is available from: Dr. Guido Radelat, Office of Research HRS-31, Federal Highway Administration, Washington, D.C. 20590.

Preliminary Documentation of Additions to the UTCS-1 Model to Provide Estimates of Vehicular Fuel Consumption Emissions, KLD Associates, Inc., for FHWA under contract DOT-FH-11-8251, August 1975.

77-067

# AUTOMOTIVE FLEET FUEL CONSUMPTION MODEL (FUEL)

The Automotive Fleet Fuel Consumption Model (FUEL) is an accounting model to evaluate the potential fuel conservation benefits attributable to the implementation of various hypothetical schedules of automotive fuel efficiency. The model was developed at the Transportation Systems Center and used by the National Highway Traffic Safety Administration in support of the 1981-84 passenger automobile average fuel economy standards, and reported in "Passenger Automobile Average Fuel Economy Standards," Federal Register, June 1977.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

J.R. Horton
U.S. Department of Transportation
Transportation Systems Center
Energy Programs Division

## MODEL TYPE

Fuel Consumption

## OBJECTIVE OF MODEL

The objective of the model is to evaluate potential fuel conservation benefits attributable to the implementation of various hypothetical schedules of automotive fuel economy. Benefits are reported in terms of (1) annual fuel savings (billions of gallons), (2) cumulative fuel savings (billions of barrels), and (3) discounted cumulative cash savings (billions of dollars).

## RELATIONSHIP TO OTHER MODELS

This model has no direct relationship to other models.

## HISTORICAL BACKGROUND

The model was constructed specifically to analyze the relative fuel conservation benefits of various schedules of automotive fuel economy for the NHTSA standards issued 6/30/77. It replaced the Fleet Accounting Model (76-007) in this function.

STRUCTURE

The FUEL model is an accounting model. It calculates fuel consumption during year i by all vehicles of age j, $FC_{ij}$, with the following formula:

$$FC_{ij} = \frac{(REG_k)\,(VM_j)\,(SURV_j)}{(FE_k)}$$

where:

i = calendar year index

j = vehicle age index

k = i - j + 1 = model year index

$FC_{ij}$ = fuel consumption by all vehicles of age j during year i

$REG_k$ = new car registrations of model year k

$VM_j$ = yearly travel of cars of age j

$SURV_j$ = likelihood of a new car surviving to age j

$FE_k$ = average new car fuel economy of model year k.

Total fleet fuel consumption during year i, $SFC_i$, is obtained from:

$$SFC_i = \sum_{j=1}^{15} FC_{ij}$$

MODEL CONSTRUCTION

Five sets of data required to run the FUEL model are presented in the model report. They are:

1) New car registrations by model year

2) Miles traveled annually by car as a function of its age

3) Schedule of vehicle survivability as a function of age

4) Average new car fuel economy by model year for existing fleet

5) Hypothetical "baseline" new car fuel economy by model year

DATA USED IN RUNNING MODEL

The user must supply a schedule of hypothetical "improved" new car fuel economy by model year.

DOCUMENTATION

Jerry Horton, Automotive Fleet Fuel Consumption Model: FUEL:FOR, Final Report, TSC, Report No. DOT-TSC-NHTSA-78-1, March 1978.

# URBAN AREA AUTOMOBILE EMISSIONS ACCORDING TO TRIP TYPE

A model of Urban Area Automobile Emissions According to Trip Type was prepared in 1974 by staff at the Environmental Protection Agency and the University of Alaska under the sponsorship of the Transportation Research Board. It may be used with traffic survey data in a metropolitan area to predict the emissions generated according to trip purpose. This information can be used for planning transit improvements to reduce emissions.

## SPONSOR

Transportation Research Board
National Academy of Sciences
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## AUTHOR

Joel L. Horowitz
U.S. Environmental Protection Agency
401 M Street SW
Washington, D.C. 20460

Lloyd M. Pernela
University of Alaska
Fairbanks, Alaska 99701

## MODEL TYPE

Emissions

## OBJECTIVE OF MODEL

This model predicts the amount of pollutant emissions that are produced by motor vehicles according to trip purpose in a metropolitan area. This information can be used to identify the strategies for reducing vehicle trips and miles traveled that would most effectively reduce emissions.

## RELATIONSHIP TO OTHER MODELS

There is no apparent relationship to other models.

## HISTORICAL BACKGROUND

The model was applied to data from two metropolitan areas: Allegheny County, PA (Pittsburgh), (reported in 1974), and Washington, D.C., (reported in 1976).

## ASSUMPTIONS

Data used were from large-scale traffic surveys done in Washington in 1968 and in Pittsburgh in 1967. It was assumed that the relative traffic patterns were the same in 1975 when the emissions estimates were made.

## VALIDATION

No known effort was made to validate the model results.

## LIMITATIONS AND BENEFITS

The model predicts only the total amount of emissions by trip type, not their distribution. The information can be used in planning transit improvements. For example, it was found that in Washington, D.C. improvements in long-range suburban bus service would reduce emissions, while in Allegheny County, Pa. demand-response bus service to the central area would be advised.

## STRUCTURE

The model structure is as follows:

$$E_p = E_p(1) + E_p(2) + E_p(3)$$

$$E_p(1) = L \sum_{i=n-16}^{n} [e_{ip}\, d_{ip}(n-i)\, m(n-i)$$

$$\times S_{ip}(v) + K_{ip}\, m(n-i)]$$

$$E_p(2) = \alpha \sum_{i=n-16}^{n} C_{ip}\, d_{ip}(n-i)\, m(n-i)$$

$$E_p(3) = \sum_{i=n-16}^{n} h_{ip}\, m(n-i)$$

where:

$E_p$ = emissions of pollutant p, kg

$E_p(1)$ = running emissions of pollutant p, kg

$E_p(2)$ = cold-start emissions of pollutant p, kg

$E_p(3)$ = hot-soak evaporative emissions of pollutant p, kg (non-zero for hydrocarbons only)

L = trip length, miles

n = calendar year 1975

$e_{ip}$ = low-mileage running exhaust emissions of pollutant p by car of model year i, kg/mile

$d_{ip}(n-i)$ = deterioration factor for pollutant p by car of model year i when it is n-i years old

m(n-i) = fraction of VMT attributable to cars of model year i in calendar year n

$S_{ip}(v)$ = speed adjustment factor for trip speed v

$K_{ip}$ = crankcase emissions of pollutant p by car of model year i, kg/mile (non-zero only for hydrocarbons)

$\alpha$ = 1 if trip begins with a cold start, 0 otherwise

$C_{ip}$ = low-mileage cold-start emissions for car of model year i, kg

$h_{ip}$ = hot-soak evaporative emissions of pollutant p by car of model year i, kg (non-zero for hydrocarbons only)

## MODEL CONSTRUCTION

This is an accounting model, for which the emissions rates used come from a variety of sources cited in the model documentation.

## DATA USED IN RUNNING MODEL

To run the model, data on trip purpose, direction, and length are needed for the entire metropolitan area.

## DOCUMENTATION

Joel L. Horowitz and Lloyd M. Pernela, "Analysis of Urban Area Automobile Emissions According to Trip Type," Transportation Research Record 492, pp. 1-8, 1974.

Joel L. Horowitz and Lloyd M. Pernela, "Comparison of Automobile Emissions Based on Trip Type in Two Metropolitan Areas," Transportation Research Record 580, pp. 13-21, 1976.

# NOISE ANNOYANCE IMPACT ALGORITHM

The Noise Annoyance Impact (NAI) Algorithm was developed at McMaster University and presented in an article in the Transportation Research Record 580, 1976, entitled, "Toward a Community Impact Measure for Assessment of Transportation Noise." The purpose of the algorithm is to provide procedures to assess the total impact on a community of transportation-produced noise. A sample application was presented to clarify the discussion and demonstrate the practicability of the noise annoyance impact measure.

## SPONSOR

National Research Council of Canada
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## AUTHOR

Fred L. Hall and Brian L. Allen
McMaster University
Hamilton, Ontario L8S 4L8

## MODEL TYPE

Noise pollution

## OBJECTIVE OF MODEL

The objective of the algorithm was to provide procedures for identifying the total impact on a community of transportation-produced noise. The noise annoyance impact measure was developed for measuring the total impact in a variety of units, such as the total number of people annoyed, the total monetary cost of the noise annoyance, etc.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models.

## HISTORICAL BACKGROUND

The authors state that concern about the noise produced by transportation facilities has led to better techniques for measuring and predicting noise, but procedures are needed to incorporate the information into an overall assessment of the noise impact on the community of a new transportation facility.

## ASSUMPTIONS

The model assumes that the sensitivity to noise of the sample population is similar to that of the whole population. It further assumes that the population annoyed by a given noise at a given location can be represented by a single function.

## VALIDATION

There is no validation of the algorithm. Rather a sample application of noise study data was used to clarify the discussion and demonstrate its practicability.

## STRUCTURE

The noise annoyance impact measure (NAI) is calculated as a double integral function of an appropriate measure of noise at a particular location, the density of people at that location, and a function that describes the annoyance effect of a given level of noise on people and that will change according to the units chosen to express NAI (e.g., total number of people annoyed, total monetary cost of the noise annoyance, etc.).

## MODEL CONSTRUCTION

This is a physical accounting model.

## DATA USED IN RUNNING MODEL

Values of the following independent variables of the equation are necessary to calculate the noise annoyance impact measure: population density at point (x,y); measure of noise at point (x,y); and annoyance effect of the noise on the population expressed in total number of people annoyed, total monetary cost of the noise annoyance, or any other appropriate unit.

## DOCUMENTATION

Fred L. Hall and Brian L. Allen, "Toward a Community Impact Measure for Assessment of Transportation Noise," Transportation Research Record 580, pp. 22-35, 1976.

# AIRPOL-4

AIRPOL-4 was designed by the Virginia Highway and Transportation Research Council and is presented in Transportation Research Record 580, 1976. The model report compares the predictive and cost performances of AIRPOL-4 with those of two other air pollution models: CALAIR (California Division of Highways) and HIWAY (U.S. Environmental Protection Agency). The results demonstrate that the predictive capability and reliability of AIRPOL-4 are generally superior to those of the other two models.

## SPONSOR

Virginia Department of Highways and Transportation
Charlottesville, Va.

## AUTHOR

William A. Carpenter and Gerardo G. Clemena
Virginia Highway and Transportation Research Council
Charlottesville, Va.

## MODEL TYPE

Air pollution/air quality

## OBJECTIVE OF MODEL

The objective of AIRPOL-4 is to predict carbon monoxide (CO) concentrations in the vicinity of roadways.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models.

## HISTORICAL BACKGROUND

AIRPOL-4 was developed as an improvement to two existing air pollution models. The existing models (CALAIR and HIWAY) were cumbersome and expensive to use. They were, furthermore, generally inaccurate and tended to severely overpredict pollution levels in the critical cases of low wind speeds and small road-wind angles.

## ASSUMPTIONS

The basic assumption of the model is that of the Gaussian line-source formulation.

## VALIDATION

The predictive performances of three models (AIRPOL-4, CALAIR, and HIWAY) were evaluated against measured data. The variables considered included wind speed, road-wind angle, atmospheric stability class, source height, and receptor location. Data from five sites in Virginia were used.

Three criteria were used in analyzing the predictive capabilities of the three models. First, mean squared errors were examined and compared among the three models. Second, regressions of actual values on predicted values were run and studied. Third, 100% confidence limits on the prediction errors were constructed.

The results demonstrated that the predictive capability and reliability of AIRPOL-4 are generally superior to those of the other two models.

## LIMITATIONS AND BENEFITS

It is significantly more cost effective to use AIRPOL-4 than CALAIR or HIWAY; the Gaussian formulation, however, is not capable of analyzing highway sections that are elevated by earthen fill.

## STRUCTURE

The basic structure is that of a Gaussian line-source air pollution model.

## MODEL CONSTRUCTION

AIRPOL-4 is a physical system model.

## DATA USED IN RUNNING MODEL

Data describing the site, traffic volumes, speeds, percentage of heavy duty vehicles, and wind direction and speed are collected to run the model.

## DOCUMENTATION

William A. Carpenter and Gerardo G. Clemena, "Evaluation and Comparison of Three Air Pollution Prediction Models," Transportation Research Record 580, pp. 76-89, 1976.

William A. Carpenter and Gerardo G.Clemena, Analysis and Comparative Evaluation of AIRPOL-4, Virginia Highway and Transportation Research Council, Rept. VHTRC 75-R55, May 1975.

# MANUAL MODEL TO PREDICT HIGHWAY RELATED CARBON MONOXIDE CONCENTRATIONS

A Manual Model to Predict Highway Related Carbon Monoxide Concentrations, dated April 1975, was prepared by the Southeast Michigan Council of Governments and the Michigan Department of State Highways and Transportation and sponsored by the U.S. Department of Transportation. The model, making use of information generally available to a highway planning agency, predicts whether a transportation facility could violate the National Ambient Air Quality Standards in southeast Michigan. Carbon monoxide concentrations are predicted and used as an indicator for other pollutants. The model is adapted from the computerized California model developed by Beaton, Skog, Ranzieri, which is now superseded by CALINE-2 (76-084).

## SPONSOR

U.S. Department of Transportation

Federal Highway Administration and
Urban Mass Transportation Administration
Washington, D.C. 20590

## AUTHOR

David A. Doctor
Southeast Michigan Council of Governments
800 Book Building
Detroit, Mich.

Michigan Department of State Highways and Transportation
Lansing, Mich.

## MODEL TYPE

Air pollution/air quality, emissions

## OBJECTIVE OF MODEL

The model is intended to predict whether a transportation facility would violate the National Ambient Air Quality Standards. It is a manual model that uses information readily available to highway planners so that alternative facilities can be quickly evaluated for possible violations for carbon monoxide and other pollutant concentration standards. Carbon monoxide concentrations are predicted and used as an indicator for other pollutant violations, such as nitrogen dioxides and hydrocarbons.

## RELATIONSHIP TO OTHER MODELS

This manual model is an adaption of the computerized California air pollution model developed by Beaton, Skog, and Ranzieri in a report entitled, Meteorology and Its Influence on the Dispersion of Pollutants from Highway Line Sources, Vol. I, 1972.

## ASSUMPTIONS

The basic assumption of the model is twofold: pollutants are immediately expanded to cell size, based on the mechanical mixing cell theory; and pollutants are then diffused by Gaussian equations to predict concentrations away from the cell.

The model further assumes that ambient pollutant concentrations are proportional to total emissions. The model does not consider spatial and temporal characteristics of air pollutants.

## VALIDATION

The model report does not discuss any validation procedures.

## LIMITATIONS AND BENEFITS

The primary benefit of the model is its manual characteristics. The look-up tables for levels of pollutant concentrations can easily be used to indicate areas where more refined analysis is needed.

The major limitations of the model are that it is not a precise predictor of carbon monoxide concentrations and other pollutants and that it is a model apparently only valid for a specific region.

In addition, more complex methods are needed because the model calculates the pollutant concentrations based on the worst meteorological and use situations. Its intended use is as an early tool in transportation planning, not as a final analytical tool.

## STRUCTURE

The model has two main equations. The first equation incorporates meteorological, traffic, mixing cell, and carbon monoxide emission variables to determine the carbon monoxide concentrations.

$$C_{mmc} = \frac{(1.06)\ (1.73\text{x}10^{-7})\ (VPH)\ (EF)\ (SAF)}{(4.24)\ (u)\ (\sin P)}$$

where:

$C_{mmc}$ = the pollutant concentration within the mechanical mixing cell

VPH = vehicles per hour

EF = the appropriate emission factor

SAF = a speed factor to adjust emissions

u = wind speed in meters/second

SinP = the sine of the wind direction

The empirical factors represent the following adjustments:

(1.06) relates the concentration increase in the mechanical mixing cell due to vertical vehicular turbulence

($1.73 \times 10^{-7}$) accounts for all unit changes in the equation, modifying it so that the resultant unit is in grams per cubic meter

(4.24) relates the concentration decrease in the mechanical mixing due to horizontal vehicular turbulence

For concentrations away from the mixing cell the Gaussian diffusion equations for height and horizontal distance are used to adjust the calculated mixing cell concentration:

$\exp[-1/2\ (\frac{H}{sz})^2]$ is used to adjust for elevated sections

$\exp[+1/2\ (\frac{Z}{sz})^2]$ is used to adjust for depressed sections

$\exp[-1/2\ (\frac{Y}{sy})^2]$ is used to adjust for horizontal distance

where:

H = height of elevated section above the receptor in meters

Z = depth of the depressed section below the receptor in meters

Y = normal distance from the receptor to the nearest edge of the highway in meters

sz = horizontal turbulent parameter in meters

sy = vertical turbulent parameter in meters

## MODEL CONSTRUCTION

This is a physical systems model.

## DATA USED IN RUNNING MODEL

The model requires the following input variables to predict concentration of carbon monoxide: the year of the prediction, the number of vehicles in the vehicle population on the highway section, the percentage of heavy-duty vehicles in the vehicle population, the average speed of the vehicles, and the vertical and horizontal distance of the receptor from the highway section.

DOCUMENTATION

David A. Doctor, A Manual Model to Predict Highway Related Carbon Monoxide Concentrations, Southeast Michigan Council of Governments, Transportation Working Paper No. 15, April 1975. NTIS No. PB-245 407/2.

COMPUTER REQUIREMENTS

There are no computer requirements since this is a manual model.

# LIGHT-DUTY EMISSION AND CONTROL COST SIMULATION MODEL

The Light-Duty Emission and Control Cost Simulation Model was prepared by Mathematica, Inc. for the Motor Vehicle Manufacturers Association (MVMA) in 1975. In general terms, the model may be used to examine the cost and the likely consequences for air quality of alternative policies and strategies for the control of pollution from mobile sources.

## SPONSOR

Motor Vehicle Manufacturers Association
300 New Center Building
Detroit, Mich.

## AUTHOR

Mathematica, Inc.
P.O. Box 2392
Princeton, N.J. 08540

## MODEL TYPE

Air pollution/air quality, emissions, vehicle user costs/vehicle operating costs

## OBJECTIVE OF MODEL

The objective of the model is to estimate the costs and effectiveness of alternative policies for achieving cleaner air. Policy alternatives examined can be evaluated according to two principal criteria: (1) the direct and indirect costs, including capital outlay and operating expenditures, and (2) the effectiveness in improving ambient air quality.

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models.

## HISTORICAL BACKGROUND

MVMA's purpose in sponsoring the study was to have an independent and objective evaluation of alternative policies to abate pollution from motor vehicles. Unlike other studies of mobile-source pollution control, the effort was to focus on the question of how can the timely abatement of pollution be encouraged rather than on questions about justifying any particular set of pollution standards or timetables for compliance.

LIMITATIONS AND BENEFITS

Limitations of the model include the following. (1) The roll-back methodology used in the ambient air quality submodel neglects knowledge about the spatial and temporal diffusion of pollution. (2) No estimates are made of the costs and effectiveness of policies designed to reduce VMT. (3) Possible changes in emission control costs over time as learning and technical change occur are not considered. (4) Pollution problems related to mobile source emissions such as noise, lead emissions, and sulfates are not included.

Benefits of the model include: (1) the capability to qualitatively analyze the economic strengths and weaknesses of current air pollution control policy; and (2) the capability to analyze alternative policies for reducing ambient air pollution and estimate the cost-effectiveness of such policies.

STRUCTURE

The model is exercised as follows. A particular strategy or set of strategies is specified along with its impact on light-duty vehicle emission rates, emission control device costs, fuel costs, VMT growth factors, etc. Then, based on data on emissions per mile of travel by light-duty motor vehicles, emissions are computed. Stationary source emissions and emissions from other vehicles and from aircraft are specified exogenously. This yields total emissions. A roll-back model is used to convert emissions figures to an estimate of their effect on ambient air quality. Capital costs and the present value of operating costs of each strategy are also calculated. The aggregation of these costs along with the effect on ambient air quality provides the basis for an assessment of the cost-effectiveness of various strategies.

There are three basic submodels contained in the full model:

1) <u>Emissions Model</u>: The emissions model combines detailed calculations of emissions for light-duty vehicles with simple growth projections of emissions from heavy-duty vehicles, motorcycles, aircraft, and stationary sources.

2) <u>Ambient Air Quality Model</u>: The ambient air quality model uses the roll-back methodology. This approach is based on the assumption that ambient concentrations less any background concentrations are proportional to total emissions.

3) <u>Cost Model</u>: The cost model evaluates the present value of the capital, operating, and maintenance costs associated with control devices applied to new and used vehicles over the simulation period.

MODEL CONSTRUCTION

Data presented in the report used to construct the model include: vehicle miles of travel, light-duty vehicle emissions factors, speed correction factors, alternative engine emissions, retrofit device effectiveness, scrappage, new car registrations, speeds, emissions from other sources, costs of controls and alternative engines, etc.

DATA USED IN RUNNING MODEL

There are two types of input data to the model. The first set reflects the impact of a particular strategy or set of strategies. This type of data includes vehicle emission rates, emission control device costs, fuel costs, etc. These inputs are then combined with the second type of data, namely those that do not vary with the strategies being simulated. These include stationary source emissions, travel growth factors, etc.

DOCUMENTATION

Policies to Abate Pollution from Motor Vehicles: An Evaluation of Some Alternatives, Mathematica, Inc., July 1, 1975, 2 volumes.

# AUTOMOBILE AND GASOLINE DEMAND MODEL

The Automobile and Gasoline Demand Model was prepared in 1975 for the Motor Vehicle Manufacturers Association (MVMA) by Data Resources, Inc. and The University of Arizona. The model was designed to determine the impact of alternative fuel economy policies on new car sales, gasoline consumption, and new car prices.

## SPONSOR

Motor Vehicle Manufacturers Association
300 New Center Building
Detroit, Mich.

## AUTHOR

Lester D. Taylor
University of Arizona
Tucson, Ariz. 85721

Philip K. Verleger and Catherine J. Hertzel
Data Resources, Inc.
29 Hartwell Avenue
Lexington, Mass. 02173

## MODEL TYPE

Fuel consumption, automobile demand, pricing, market share

## OBJECTIVE OF MODEL

The objective of the model is to determine the impact of alternative fuel economy policies on new car sales, the composition of new car sales, gasoline consumption and used car prices.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models.

## ASSUMPTIONS

The following basic assumptions are the foundation of the gasoline and auto demand model:

1) The demand for new cars is determined indirectly as a function of the desired number of car miles to be traveled.

2) The number of new cars sold is an input to a set of segment

equations which determines the composition of new car sales in terms of weight, horsepower, etc.

3) In the long run the ratio of used car prices to new car prices is determined by the gasoline efficiency of used cars relative to the gasoline efficiency of new cars and the cost of maintenance.

4) The demand for gasoline is derived from the demand for travel.

## VALIDATION

There is no validation of the model since it had not been estimated with actual data in the report.

## LIMITATIONS AND BENEFITS

The authors report that the model possesses the following benefits:

1) The demand for new cars and the demand for gasoline are approached in the framework of an integrated model that sees both demands as being derived from the demand for motor-car transportation.

2) The demand for an equilibrium car stock (which itself derives from the demand for a desired number of car-miles to be traveled) is formulated as a function of the level of income and the user-cost of motor-car travel.

3) A shortfall of actual car stocks from desired car stocks is assumed to affect the demand for new cars through the used car market rather than directly.

4) The short-run demand for gasoline is derived from the selection of a utilization rate of the existing car stock.

## STRUCTURE

The model reported is an analytical model of gasoline and auto demand. As presented, it is ready to be estimated and tested, but this has not been done because of limited resources.

The model contains four main components:

1) Demand for new cars

2) Determination of used car prices

3) Composition of new car sales

4) Demand for gasoline

A typical equation specification is:

$$E_T = M_T \sum_i \frac{q_i \, e_i}{M_{Li}} + \frac{1}{M_T} \sum_j \sum_i s_i \, r_{ij} \, m_{ij} \, g_{ij}$$

where:

$E_T$ = average total energy consumed per mile in period T

$M_T$ = total demand for car miles in period T

$q_i$ = number of vehicles of type i of all vintages on the road in period T

$e_i$ = amount of energy input into construction of a vehicle of type i

$M_{Li}$ = expected number of total miles of vehicle of type i over its lifetime

$s_i$ = share of vehicles of type i in total sales

$r_{ij}$ = percentage of cars of type i of vintage j remaining on the road in period T

$m_{ij}$ = average miles per period driven by a vehicle of type i and vintage j

$g_{ij}$ = average gallons per mile consumed by a vehicle of type i and vintage j

MODEL CONSTRUCTION

An estimation of the model was not done; therefore no data were used in building the model.

DATA USED IN RUNNING MODEL

It is not clear what data are necessary to run the model.

DOCUMENTATION

L.D. Taylor, P.K. Verleger, and C.W. Hirtzel, "The Welfare Effects of Fuel Economy Policies", July 1975. The report is available from MVMA or through NTIS.

# AUTOMOBILE DEMAND EQUATIONS

Several automobile demand equations were estimated by Alan C. Hess of the University of Washington and published in Econometrica, April 1977. The models were built to investigate three main issues: the length of the household planning horizon; the range of substitution among assets; and the relative importance of substitution and wealth effects. The equations were estimated over the same set of data to reflect different assumptions about the planning horizon and range of substitutions among assets.

## AUTHOR

Alan C. Hess
University of Washington
Seattle, Wash. 98195

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the models is to answer the following questions concerning automobile stock demand: (1) whether the household is better viewed as planning over a single-period or a multi-period horizon; (2) whether the household is better viewed as planning in a single-asset or a multi-asset framework; and (3) what is the relative importance of substitution and wealth effects as sources of change in the stock demand for automobiles. It was not an objective to build an operational simulation model.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other operating forecasting models.

## ASSUMPTIONS

The basic assumption from which the alternative household automobile demand equations in this study are derived is that the goal of the household is to maximize the value of a lifetime utility function which is the sum of each period's utility discounted by a time preference parameter.

## VALIDATION

There is no validation outside the sample period for the various equations. Within-sample summary statistics are presented. Elasticities for several alternative equation specifications are calculated.

## STRUCTURE

Four basic single-equation specifications were examined. They were:

1) Multi-period, multi-asset model.

2) Multi-period, single-asset model.

3) Single-period, single-asset model.

4) Single-period, multi-asset model.

The multi-period, multi-asset model was judged to be superior to the other three specifications. The following additional conclusions were drawn: (1) the household is better viewed as planning over a multi-period as compared to a single-period horizon with respect to automobile stock demand; (2) the household is better viewed as substituting between consumption, autos, durable goods, and housing rather than just between consumption and autos; and (3) substitution effects have larger impacts on auto stock demand than do wealth effects. In comparison with the wealth effects, substitution effects account for approximately seven times more of the variation in auto stock demand.

## MODEL CONSTRUCTION

The data base used to estimate the model includes implicit price deflators for autos, other goods, residences, and personal consumption, inflation rates, interest rates, disposable income, wealth, households, and real stock of autos.

## DATA USED IN RUNNING MODEL

An operational forecasting model was not constructed.

## DOCUMENTATION

Alan C. Hess, "A Comparison of Automobile Demand Equations," Econometrica, April, 1977, pp. 683-701.

## COMPUTER REQUIREMENTS

Not applicable.

# ESTIMATING AUTO EMISSIONS OF ALTERNATIVE TRANSPORTATION SYSTEMS

Estimating Auto Emissions of Alternative Transportation Systems, dated April 1972, was written by the Metropolitan Washington Council of Governments under the sponsorship of the U.S. Department of Transportation. The objective of the model is to estimate the magnitude of carbon monoxide, hydrocarbons, and oxides of nitrogen from automobile emissions for alternative regional transportation systems. The estimates are made relative to the baseline of no improvements in the transportation system, i.e., zero-control strategy.

## SPONSOR

U.S. Department of Transportation
Office of the Assistant Secretary for Environment and Urban Systems
Washington, D.C. 20590

## AUTHOR

Sydney D. Berwager and George V. Wickstrom
Metropolitan Washington Council of Governments
Department of Transportation Planning
1225 Connecticut Avenue NW
Washington, D.C. 20036

## MODEL TYPE

Emissions, air pollution/air quality, vehicle miles traveled, automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to estimate the magnitude of carbon monoxide, hydrocarbons, and oxides of nitrogen from automobile emissions for alternative regional transportation systems.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models. However, a portion of the program logic is based on model development by the Tri-State Transportation Commission for estimating highway facility requirements.

## HISTORICAL BACKGROUND

The introduction to the model report states that the model was developed to bring social and environmental factors into the decision-making framework that engineering concerns enjoy.

## ASSUMPTIONS

The major assumption is that air pollutant emissions rates are a function of the age distribution of automobiles, average emissions factors of autos of age t, vehicle miles traveled, and socio-economic characteristics of the population. Truck emissions rates were not considered to be a significant part of total emission rates, and therefore, are not part of the model. Various assumptions were made about the layout of different highway systems and transit alternatives.

## VALIDATION

There are no validation procedures discussed in the model report.

## LIMITATIONS AND BENEFITS

The primary benefit of the model is its simplicity. It is an analytical tool which can be used to rapidly evaluate the relative magnitude and location of auto emissions for alternative regional transportation systems.

A major limitation of the model results from the method of constructing traffic volumes. These volumes were determined from relationships between vehicle-miles of travel, the use of different types of facilities, vehicle trip origin density, and expressway capacity. This bypassed the traditional and expensive process of determining origins and destinations for all future trips, assigning them to links in the network, and estimating speeds on each link. Therefore, estimates of traffic volumes only represent average conditions across each sub-area. The full range of operating conditions found within a sub-area is not modeled.

## STRUCTURE

The model consists of the following three sub-models:

1) The trip generation submodel computes vehicle trip origins by sub-area from socio-economic data and transit system characteristics.

2) The travel description submodel computes vehicle miles of travel (VMT) and speeds by the highway facility type from vehicle trip origin estimates and highway supply data.

3) The pollutant emissions submodel estimates the carbon monoxide, hydrocarbon, and nitrogen oxides emissions rates for each sub-area from average speed and VMT data.

## DATA USED IN RUNNING MODEL

The following categories of data are required to run the model:

vehicle trip origins, population, employment, automobile ownership, vehicle miles of travel, vehicle ages, highway system description, automobile emission rates, sub-area description, and transit system alternatives.

Descriptions of future highway facilities are required for alternative highway analysis and estimates of air pollutant emissions rates.

DOCUMENTATION

Sidney D. Berwager and George V.Wickstrom, Estimating Auto Emissions of Alternative Transportation Systems, Report No. DOT-05-20004, April 1972. NTIS No. PB-208 914.

COMPUTER REQUIREMENTS

The model programs are operational on an IBM 360 Model 50.

# MATHAIR

MATHAIR was prepared in 1976 by MATHTECH, Inc. for the Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency. The model enables the user to perform experiments evaluating the impact of air pollution control strategies in different geographic regions. For each particular strategy, the model calculates both the effect on air quality and the dollar benefits and costs associated with that strategy for a user-specified geographic region. The calculations are made relative to a baseline of zero-control strategy.

## SPONSOR

U.S. Environmental Protection Agency
Corvallis Environmental Research Laboratory
Office of Research and Development
Corvallis, Ore. 97330

## AUTHOR

MATHTECH, Inc.
P.O. Box 2392
Princeton, N.J.

## MODEL TYPE

Air pollution/air quality, emissions, vehicle miles traveled, modal split.

## OBJECTIVE OF MODEL

The objective of the MATHAIR Model is to estimate the impact of strategies for controlling mobile source air pollution for both the effect on air quality and the associated benefits and costs (in dollars).

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models. However, parameters estimated by Charles River Associates of Cambridge, Mass., in a study of Pittsburgh (March 1972) were used to calibrate the Transportation Model of MATHAIR.

## HISTORICAL BACKGROUND

MATHAIR was developed to be used as an analytical tool in the ever-present controversy over air pollution standards.

## ASSUMPTIONS

One important assumption of the model is that the benefits of a particular air pollution control strategy are calculated in dollar terms. It is therefore possible to calculate the net benefits of any particular strategy since costs are also in dollars. Many models and analyses of air pollution control only estimate their benefits in physical terms, which then dictates a cost-effectiveness approach as opposed to a cost-benefit one.

## VALIDATION

Sensitivity analysis was performed on MATHAIR to determine which inputs have a critical effect on strategy outcomes. The following three experiments were conducted:

1) The first experiment assumed an accelerated rate of removing automobiles from the stock. This was estimated to have a minimal effect on policy implications.

2) The second experiment simulated a set of "worst case" assumptions for Los Angeles: increased control device costs, low baseline dollar damages due to air pollution and low estimates of the pollutant reduction efficiencies of auto control devices. The combined impact of these assumptions resulted in a dramatic decrease in net benefits.

3) The last experiment simulated three versions of the strictest control strategy, each containing a different transportation control measure. The marginal cost of the strategy exceeded the marginal benefit in all cases.

Several of the output series of the transportation model were compared with an independent data series. It was shown that the percentage of trips predicted by the model originating in central city or suburb by mode is similar in four major metropolitan areas to figures from the 1974 Urban Transportation Factbook.

## LIMITATIONS AND BENEFITS

A unique feature of MATHAIR is that it includes, on the cost side, the cost incurred when a traveler abandons his preferred mode of transportation and either switches to a less convenient mode or foregoes the trip altogether. Using the number and prices of different types of trips, the cost module of the model calculates the cost to travelers of reduced (or enhanced) mobility due to transportation control measures.

A limitation of MATHAIR is contained in the air quality module of the model. A simple linear rollback model is used for predicting air quality. This formulation is based on the assumption that ambient pollutant concentrations are proportional to total emissions. This approach fails to consider information on the spatial and temporal diffusion of pollution. The estimated rollback coefficients may also be subject to considerable error since they are derived from data on pollution emissions and concentrations for a single base year.

STRUCTURE

MATHAIR consists of the following six modules (or sub-models):

1) Automobile Stock Module--computes the composition of the auto stock.

2) Transportation Model--forecasts vehicle miles of travel for each mode of transportation.

3) Emissions Module--calculates pollution emissions for mobile sources and stationary sources subject to the installation of control devices.

4) Air Quality Module--calculates ambient concentrations of the pollutants.

5) Benefits Module--calculates dollar losses due to pollution damage and the benefits (i.e., reduction in losses) with respect to a baseline case.

6) Cost Module--calculates the cost of implementing the control strategy.

The output of a MATHAIR simulation contains the following information:

1) Predicted emissions (tons/day) of carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and lead from automobiles, from all mobile sources, and from all stationary sources, respectively.

2) Predicted ambient concentrations (ppm) of carbon monoxide, nitrogen oxides, oxidants, and sulfur oxides and of lead (mean $g/m^3$).

3) Discounted costs and benefits for the strategy which has been simulated.

The outputs above are generated for each year of the simulation horizon. Additional output includes:

4) Discounted present value of benefits and costs over the complete forecast period.

5) Detailed output of the transportation module. This includes the number of passenger trips, passenger miles, and vehicle miles for each type of trip as well as mode-split and trip frequency probabilities.

## MODEL CONSTRUCTION

MATHAIR is an accounting model.

## DATA USED IN RUNNING MODEL

Six categories of data, corresponding to the six MATHAIR modules, are required for a MATHAIR simulation run. The data include: new auto registrations, scrappage, parking costs, trip length, speed, time and fare, modal split parameters, number of trips, vehicle occupancy, vehicle miles traveled, emissions factors and costs, control strategy costs, etc.

The input data required for the MATHAIR Model are described in detail in the model report.

## DOCUMENTATION

MATHTECH, Inc., A Computer Simulation Model for Analyzing Mobile Source Air Pollution Control Sept. 1976, EPA-600/5-76-100. NTIS No. PB-260 877.

## COMPUTER REQUIREMENTS

All MATHAIR programs and data are stored as files on an IBM 371-68. The model can be accessed through the NCSS time-sharing computer network.

76-080

# PRICING IN THE AUTOMOBILE INDUSTRY: A SIMPLE ECONOMETRIC MODEL

"Pricing in the Automobile Industry: A Simple Econometric Model" was written at Virginia Commonwealth University and Mary Washington College and published in the Southern Economic Journal, V. 43, No. 1, 1976. The purpose of the model is to test the importance of various cost factors and administered pricing in the determination of auto prices.

## AUTHOR

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John Albertine
Mary Washington College
Fredricksburg, Va. 22401

## MODEL TYPE

Pricing

## OBJECTIVE OF MODEL

The objective of the model is to test the relative importance of cost factors and anticipated market demand in the determination of auto prices.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models.

## HISTORICAL BACKGROUND

The authors state the model was developed to contribute to the debate concerning the reasons for the increases in auto prices in 1974 and 1975 in spite of decreased sales volume.

## ASSUMPTIONS

The model assumes that the wholesale price of new cars is a function of factor costs and anticipated growth in sales volume. It assumes also that pricing decisions for new car models are made in mid-summer, so the annual price index is constructed with July values.

## VALIDATION

There is no validation of the model outside the sample period. The usual summary statistics (t-ratios and $R^2$) are presented with the estimated equation. Results of exercising the model are:

1) Factor costs and anticipated strength of domestic new car sales were found to be significant determinants of wholesale auto prices.

2) Factor costs were the most significant determinant of price changes.

3) Contrary to the administered pricing hypothesis, wholesale new car prices were estimated to be a direct function of anticipated market demand.

4) Market forces have become a stronger influence on new car prices more recently.

## STRUCTURE

The single equation model is of the form:

$$P_t = A_0 + A_1 (V_t) + A_2 (C_{t-1})$$

where:

$P_t$ = a wholesale price index for autos in year t

$V_t$ = a variable indicating expected growth in sales volume in year t

$C_{t-1}$ = a composite cost index for auto manufacturing

## MODEL CONSTRUCTION

The model was estimated with annual data from 1953-1975.

Specific data are:

1) Bureau of Labor Statistics wholesale price index for new cars.

2) Published estimates of General Motors for approaching model year sales volume.

3) Bureau of Labor Statistics wholesale price index for materials in durable manufacturing.

4) Bureau of Labor Statistics series on gross hourly wage rates for the motor vehicle and parts industry.

## DATA USED IN RUNNING MODEL

Historical data or assumed future values for the independent variables are necessary to generate predictions for the wholesale price index for new cars.

## DOCUMENTATION

G. Hoffer, J. Marchand, and J. Albertine, "Pricing in the Automobile Industry: A Simple Econometric Model," Southern Economic Journal, Vol. 43, No. 1, 1976.

# THE MOTOR VEHICLE EMISSION AND COST MODEL (MOVEC)

The Motor Vehicle Emission and Cost Model (MOVEC), published in December 1973, was developed by the Rand Corporation as part of the Clean Air Project of San Diego County's Environmental Development Agency under the sponsorship of the U.S. Environmental Protection Agency. The MOVEC model permits an evaluation of alternative light-duty motor vehicle retrofit and inspection/maintenance strategies. For specified strategies, the total annual costs (both purchase and operating) are calculated for the region.

## SPONSOR

Office of Environmental Management
Environmental Development Agency
County of San Diego, California
(under a grant from the U.S. Environmental Protection Agency)

## AUTHOR

W.T. Mikolowsky
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Air quality, emissions, economic impact, vehicle user costs/vehicle operating costs.

## OBJECTIVE OF MODEL

The Motor Vehicle Emissions and Cost Model (MOVEC) was developed for use in analyzing the impact of motor vehicle emissions on an urban region. The main purpose of MOVEC is to analyze light-duty motor vehicle emissions for any specified calendar year between 1960 and 1999. Several attendant features of the model are that it:

1) applies user-specified additional emission control strategies to vehicles in selected 1955-1974 model years;

2) calculates the total annual costs that a region would incur by mandating a particular retrofit-inspection/maintenance control strategy;

3) calculates the distribution of costs among various income groups for three different payment schemes by which the cost of the control strategy might be funded;

4) plots four emission parameters for various pollutants versus annual cost of different strategies for a given calendar year; and

5) plots four emission parameters versus calendar year for a time history of the region with a given control strategy in force.

RELATIONSHIP TO OTHER MODELS

MOVEC is one of several models developed by the Rand Corporation to identify strategies for meeting of the National Air Quality Standards in San Diego as specified by the 1970 Amendment to the Clean Air Act. The models and methods were designed to emphasize breadth rather than depth of impact. Although the models were designed to San Diego's particular characteristics, they have been made purposely general enough for use in similar studies of other regions. The methodology and models used in the Clean Air Project include:

1) Fixed Source Analysis Techniques to evaluate the cost and effectiveness of controls on fixed sources;

2) MOVEC evaluates the cost and effectiveness of retrofit and inspection/maintenance strategies for in-use vehicles;

3) Transportation Model evaluates the costs and effects of transportation management strategies;

4) Bus System Cost Model evaluates the annualized costs of providing a particular quality and quantity of bus service for a region;

5) Tradeoff Model evaluates retrofit-inspection/maintenance control strategies and transportation management strategies for a given fixed source control strategy;

6) Air Quality Model determines the percentage reduction in base year (1970) emissions required to meet each air quality standard;

7) Larsen Model estimates how air quality varies between different parts of the region; and

8) Total Base Year Emissions compiles a 1970 emissions inventory estimating both fixed and mobile sources.

ASSUMPTIONS

The following explicit assumptions were noted in the model report:

1) The vehicle population and mileage distributions by age of vehicle are static;

2) The vehicle emissions for each model year are described by average emission factors for exhaust, evaporative, and blowby sources expressed in terms of grams per mile;

3) The full implication of a control strategy is assumed to occur wholly within one analysis year, and annualized costs are

calculated on that basis;

4) Deterioration and speed correction factors apply only to the exhaust emissions, while crankcase blowby and evaporative emissions remain at the level specified for a new vehicle;

5) 1975 and later model year vehicles are excluded from retrofit strategies because they are assumed to meet the federal emission standards for hydrocarbons, carbon monoxide, and the California standards for oxides of nitrogen with original equipment;

6) It is assumed that a linear relationship exists between ambient pollutants and total emissions; and

7) It is assumed that certain emission species serve as proxy for ambient concentrations of other species; reactive hydrocarbons for oxidant, nitrogen oxides for nitrogen dioxide, and sulfur oxides for sulfur dioxides.

## VALIDATION

The model report does not discuss specific validation efforts for this model.

## LIMITATIONS AND BENEFITS

A unique feature of the MOVEC model is the flexibility of its data base. MOVEC is structured to provide a computational framework that will readily permit new technical assumptions concerning emission factors, effectiveness of controls, costs, and other new data to be incorporated. Since the impacts of the control strategies are strongly dependent on the technical assumptions, it is important that MOVEC permits "latest" scientific information to be incorporated in analysis.

MOVEC is coupled to a computer graphics system which produces two kinds of plots: cost plots and time plots.

## STRUCTURE

MOVEC consists of the following modules:

1) vehicle population distribution by age of vehicle;

2) vehicle mileage distribution by age of vehicle;

3) vehicle emissions without additional controls;

4) vehicle emissions under a control strategy;

5) incremental costs of a control strategy to the region; and

6) distributional impacts: costs to different income groups.

For a particular year and set of strategies, MOVEC reports the emissions by species (total and reactive hydrocarbons, carbon monoxide, nitrogen oxides, sulfur dioxide, lead and particulate matter) in the following way:

1) regional light-duty motor vehicle emissions;

2) regional reduction of light-duty motor vehicle emissions resulting from the control strategy;

3) total regional emissions from all sources;

4) total regional emissions in excess of the regional standards;

5) total regional annualized cost of the control strategies; and

6) distributional impacts by income group for financing the control strategies.

## MODEL CONSTRUCTION

MOVEC is a physical accounting model.

## DATA USED IN RUNNING MODEL

The data base necessary to run the model includes: effectiveness and cost of the light-duty motor vehicle retrofit and inspection/maintenance control tactics; vehicle population distribution by age of vehicle; vehicle mileage distribution by age of vehicle; new vehicle emission factors by model year; age-deterioration factors for exhaust emissions; speed correction functions for exhaust emissions; regional income distribution data; and vehicle ownership by income group.

## DOCUMENTATION

W.T. Mikilowsky, The Motor Vehicle Emission and Cost Model (MOVEC): Model Description and Illustrative Applications, Rand Corporation, R-1364-SD/Appendix 2, December 1973.

Bruce L. Goeller, San Diego Clean Air Project, Rand Corporation, R-1364-SD, December 1973.

## COMPUTER REQUIREMENTS

MOVEC was developed on the IBM 370/158 computer and is designed to be coupled with an S-C 4060 computer graphics system. However, the graphics system is not required for most of the model output.

# CALINE-2: CALIFORNIA LINE SOURCE DISPERSION MODEL

The California Line Source Dispersion Model, called CALINE-2, is designed to predict the level of carbon monoxide adjacent to, and dispersed from, a line source such as a highway. The latest version was developed in 1977 by the California Department of Transportation under the sponsorship of the Federal Highway Administration and may be used to assess the impact on air quality of proposed highway improvements.

## SPONSOR

U.S. Department of Transportation
Federal Highway Administration
Offices of Research and Development
Washington, D.C. 20590

## AUTHOR

C.E. Ward Jr., A.J. Ranzieri, E.C. Shirley
California Department of Transportation
Office of Transportation Laboratory
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Sacramento, Calif. 95819

## MODEL TYPE

Air pollution/air quality

## OBJECTIVE OF MODEL

This model simulates the dispersion of carbon monoxide pollution from a line source, such as a highway, using the Gaussian dispersion theory. It is intended for use in assessing the impact on air quality of proposed transportation projects as a part of a required Environmental Impact Report.

## RELATIONSHIP TO OTHER MODELS

There is no apparent relationship to other models.

## HISTORICAL BACKGROUND

CALINE-2 is the second major version of the California Line Source Dispersion Model developed by the California Department of Transportation. It supersedes the earlier version, called CAL%DISP, developed in 1972.

## ASSUMPTIONS

Gaussian dispersion equations are the basis of the model. The model assumes that winds are uniform, emissions are continuous, pollutants are dispersed from a region in the highway right-of-way called the "mixing cell," and predictions are only made above ambient levels.

## VALIDATION

An air sampling study was done at four locations on the Los Angeles freeway system, and the observed dispersed pollution levels were compared with the predictions of the model using regression analysis. The model was found to predict best at sites with depressed roadways and parallel winds, but it generally came reasonably close to predicting actual conditions.

## LIMITATIONS AND BENEFITS

This model as designed is suitable only for predicting the dispersion of carbon monoxide, but it represents the present state-of-the-art for this purpose. It predicts pollution levels only in the micro-scale area adjacent to the line source.

## STRUCTURE

The general form of the Gaussian diffusion equation is:

$$C(x,y,z;H) = \frac{QF}{2\pi s_y s_z U} \left[\exp\left(\frac{-1}{2}\left[\frac{y}{s_y}\right]^2\right)\right]$$

$$\left[\exp\left(\frac{-1}{2}\left[\frac{Z+H}{s_z}\right]^2\right) + \exp\left(\frac{-1}{2}\left[\frac{Z-H}{s_z}\right]^2\right)\right]$$

where:

$C$ = concentration, ppm or mean $g/m^3$

$x,y,z$ = receptor location in 3-dimensional space, meters

$H$ = effective stack height, meters

$Q$ = source strength, gms/sec

$s_y, s_z$ = horizontal and vertical dispersion parameters, meters

$U$ = mean wind speed, meters/sec

$F$ = conversion factor to change input units to output units

The equation is varied depending on wind direction.

## MODEL CONSTRUCTION

This is a physical model formulated on the basis of mathematical relationships.

## DATA USED IN RUNNING MODEL

To run the model the following must be used for input: traffic volume, average emissions, wind speed and angle, surface atmospheric stability, pavement elevation and width, and receptor distance from the road and height from the ground.

## DOCUMENTATION

C.E. Ward Jr., A.J. Ranzieri, and E.C. Shirley, CALINE-2: An Improved Microscale Model for the Dispersion of Air Pollutants from a Line Source, California Department of Transportation, June 1977.

The report is reproduced in Assessing Transportation-Related Air Quality Impacts, Special Report 167, Transportation Research Board, p. 97, 1976.

## COMPUTER REQUIREMENTS

The source program listing and sample runs are included in K.E. Jones and A. Wilbur, A User's Manual for the CALINE-2 Computer Program, Environmental Design and Control Division, Offices of Research and Development, Federal Highway Administration. A magnetic tape containing the program is available from NTIS. The program is written in FORTRAN IV.

# DYNAMIC MODEL OF THE U.S. AUTOMOBILE FLEET

A Dynamic Model of the U.S. Automobile Fleet was prepared in 1977 by the Environmental Impact Center, Inc. for the Transportation Systems Center. Its purpose is to explain dynamically the properties of the overall U.S. automobile fleet.

## SPONSOR

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

## AUTHOR

F.T. Rabe
Environmental Impact Center, Inc.
55 Chapel Street
Newton, Mass. 02158

## MODEL TYPE

Fleet size

## OBJECTIVE OF MODEL

The objective of the model is to simulate dynamically the properties of the automobile fleet, including new car sales, scrappage, and total fleet size. Equation specifications and estimates empirically developed in other studies were incorporated into this model.

## RELATIONSHIP TO OTHER MODELS

Other work incorporated in the development of this model includes that of Rand (74-001A,B,C), Chase (74-002A,B), TSC, General Motors, etc.

## HISTORICAL BACKGROUND

This model was developed under the Transportation Systems Center's Transportation Energy Efficiency Program.

## ASSUMPTIONS

The automobile fleet was disaggregated by age only.

## VALIDATION

Comparisons were made between the model's predictions and actual values for the years 1960, 1965, and 1970. The model did a poor job of predicting actual trends; this was judged by the model author to be due to the equation specifications by Rand. Sensitivity analyses were also performed.

## LIMITATIONS AND BENEFITS

The relationships derived in previous studies lend empirical credence to the model. This was a test made to see if a group of independently estimated parametric relationships could be amalgamated. Most other models explicitly represent new car sales and fleet size with scrappage as the residual; this model tests the approaches of modeling scrappage and sales with fleet size as the residual and modeling scrappage and fleet size with sales as the residual. The model does not include a mechanism for limiting the growth of the fleet when a saturation point has been reached.

## STRUCTURE

The fleet is disaggregated into the initial age group, which is dependent on new car sales, the intermediate age group, and the terminal age group. All three of these age groups feed into both the total fleet size and scrappage. Either fleet size, sales, and scrappage may be determined by varying econometric specifications, or one of them may be dynamically simulated as a result of the other two. For example, a typical equation is:

$$F_t = F_{t-1} + NCS_{\Delta t} - S_{\Delta t}$$

where:

$F_t$ = fleet size at time t

$F_{t-1}$ = fleet size at time t-1

$NCS_{\Delta t}$ = new car sales between t-1 and t

$S_{\Delta t}$ = scrappage between t-1 and t

## MODEL CONSTRUCTION

Since this model is based on the estimates of other studies, no data were required to estimate it. The model is constructed using the System Dynamics approach to modeling, which was developed by the System Dynamics Group at the Massachusetts Institute of Technology.

## DATA USED IN RUNNING MODEL

The following may be required input to the model: the price of new cars, the price of used cars, household income, the ten-year average of used-car prices, the effect of mileage on scrappage, the price of gasoline, the number of drivers per household, the average fleet fuel economy, and the initial stock of automobiles.

## DOCUMENTATION

F.T. Rabe, Dynamic Models of the U.S. Automobile Fleet, Environmental Impact Center, Inc., prepared for U.S. Department of Transportation, under Contract No. TS-9961, August 1977.

## COMPUTER REQUIREMENTS

This model is programed in the DYNAMO language, which is especially suited to the Systems Dynamics modeling approach. See A.L. Pugh III, DYNAMO Users Manual, 3rd Edition, MIT Press, 1967.

# DETERMINANTS OF SCRAPPING RATES FOR POSTWAR VINTAGE AUTOMOBILES

A model of the Determinants of Scrapping Rates for Postwar Vintage Automobiles by Richard W. Parks was sponsored by the National Science Foundation and was published in Econometrica, July 1977. The model analyzes U.S. produced automobiles for the years 1947 through 1973. Probabilities that a car will be scrapped are dependent upon the car's age, make, relative cost of repairs, and durability characteristics.

## SPONSOR

National Science Foundation
1100 G Street, N.W.
Washington, D.C. 20550

## AUTHOR

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Seattle, Wash. 98195

## MODEL TYPE

Scrappage

## OBJECTIVE OF MODEL

The objective of the model is to describe scrapping rates for U.S. produced automobiles as a function of the specific make, age, relative cost of repairs, and durability characteristics.

## RELATIONSHIP TO OTHER MODELS

There is no direct relationship to other models.

## HISTORICAL BACKGROUND

The responsiveness of scrappage rates to economic variables has important implications for attempts to regulate automobile characteristics, as cost changes brought about by regulations may have an effect on scrappage rates.

## ASSUMPTIONS

The model is based on the following assumptions:

1) Durability characteristics are simplified into a single parameter

called durability, represented by d, for all a-year old cars.

2) Cars of all ages provide the same level of transportation services.

3) Rental or service cost of a car is its present discounted value of the expected cost of providing a continual service plan.

4) Scrapping rate is described in terms of conditional probabilities, conditional on survival of the car to age a and increasing with age of car.

## VALIDATION

There are no validation procedures discussed in the model report. The results consist of regressions of the logit of postwar domestic automobile scrapping rates on economic and dummy variables. The ratio of new car prices to repair prices is the only significant observation-year variable. The regressions account for about 90 percent of the variation in the logit of scrapping rates for most makes. The age variables account for a major part of the variance in the dependent variables. The sets of vintage coefficients are significant for most of the makes. Registration data for 1973 were compared with predicted 1973 data for age and vintage variables. The predicted results were consistent with observed values at the 5 percent level of significance.

## LIMITATIONS AND BENEFITS

The primary benefit of the model can be found in the scrappage function.

## STRUCTURE

An econometric model is constructed which expresses the probability that a car will be scrapped as a function of the car's age, the relative cost of repairs, and the durability characteristics of the car. The durability characteristics are hypothesized to be influenced by economic variables anticipated at the time of manufacture. The scrappage rates are fitted to a logit function:

$$\ln\left(\frac{L_{mav}}{1 - L_{mav}}\right) = d_{mv} + age_{ma} + b_m + C_m\left(\frac{P_v}{q_t}\right)$$

$L_{mav}$ = probability that a car of model type m, age a, and vintage v, will fail to survive to age a + 1.

$d_{mv}$ = make-vintage dummy variable

$age_{ma}$ = age dummy variable

$b_m$ = constant term for model type m

$C_m$ = coefficient

$P_v$ = new car price index for vintage v cars

$q_t$ = index of automobile repairs in year t

The age variable dominates the regressions, and the repair price variable enters significantly. The vintage variables also enter significantly in many of the regressions. However, the values of the vintage variables cannot be explained by movements in economic variables associated with the vintage year, as was hypothesized.

## MODEL CONSTRUCTION

The following data were required to build the model: the number of automobiles registered in the U.S. cross-classified by make and model for years 1936-1967, from Automotive Industries Annual Statistical Issue and the R.L. Polk Company; the cost of new automobiles (Bureau of Labor Statistics Consumer Price Index, New Car Price, Series K-3); the index of the price of automobile repairs (Bureau of Labor Statistics, Consumer Price Index, Auto Repairs and Maintenance Index); the interest rate series for years 1924-1973; the index of price of scrap steel (constructed from the Pittsburgh price series for scrap steel reported in various issues of The Survey of Current Business).

## DOCUMENTATION

Richard W. Parks, "Determinants of Scrapping Rates for Postwar Vintage Automobiles," Econometrica, Volume 45, No. 5, July 1977, pp.1099-1115.

# CONSUMPTION OF GASOLINE BY HOUSEHOLDS

Two models are developed in the Rand study entitled "The Economic Impact of Automobile Travel Cost Increases on Households," to determine the effects of governmental policy options for conserving gasoline and improving air quality on families that own and operate automobiles in the United States. Specifically, the study is concerned with the income distribution effects of governmental policy options that may cause the costs of owning and operating a car to increase. These models were reported in 1977 and sponsored by the National Science Foundation and the Federal Energy Administration. The first model, Consumption of Gasoline by Households, which is described here, focuses on the initial impacts of an increased gasoline tax on households. The authors conclude that such a gasoline tax is regressive because the tax would be more of a burden to a poorer family than to more wealthy families.

The second model is described in 77-087B.

## SPONSOR

National Science Foundation
Washington, D.C. 20550

With additional Support from:
Federal Energy Administration
Washington, D.C. 20461

## AUTHOR

J.P. Stucker and T.F. Kirkwood
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Vehicle miles traveled, fuel consumption

## OBJECTIVE OF MODEL

The purpose of this model is to examine the initial impact of gasoline price increases, specifically gasoline tax increases, on households of different incomes.

## RELATIONSHIP TO OTHER MODELS

This model was developed in conjunction with the Household Expenditures on Automobile Ownership and Operation Model (77-087B).

## HISTORICAL BACKGROUND

In the past the gasoline tax was commonly assumed to be extremely regressive. More recent studies conclude that a gasoline tax may not be regressive. However, most of these recent studies are limited because they use national or state aggregate data. The Rand study uses survey data disaggregated by household income levels. An analysis of these data provide better insight on whether a gasoline tax is regressive.

## VALIDATION

To validate the model results, data from the National Personal Transportation Survey were used. The results of the validation effort indicated similar trends in the income elasticities by income group.

## LIMITATIONS AND BENEFITS

The analysis assumes that all households within an income group have similar driving habits. This is certainly not true for lower income households since only one-half of these households have access to a car. Thus, half of these households would not share the burden of a gasoline tax and the other half would feel the tax more severely than indicated in the analysis.

## STRUCTURE

Several small models are estimated. The model results are examined to determine the relationship between gasoline expenditures and household income.

Two results of the models are that (1) the income elasticity of household auto miles driven is near 1.0 for lower income families, and this elasticity decreases with income; and (2) the income elasticity of household gasoline consumption has a similar trend.

## MODEL CONSTRUCTION

The data used to build the models were obtained from the 1973 Lifestyles and Energy Supply Survey collected by Response Analysis Corporation for the Washington Center for Metropolitan Studies.

Other data used in the analyses were Environmental Protection Agency estimates of automobile fuel economy, and 1969 and 1970 survey data from the Nationwide Personal Transportation Study of the U.S. Department of Transportation.

## DOCUMENTATION

J.P. Stucker and T.F. Kirkwood, <u>The Economic Impact of Automobile Travel</u>

_Cost Increases on Households_, R-1842-NSF/FEA, The Rand Corporation, July 1977.

# HOUSEHOLD EXPENDITURES ON AUTOMOBILE OWNERSHIP AND OPERATION

Two models are developed in the Rand study entitled, "The Economic Impact of Automobile Travel Cost Increases on Households," to determine the effects of governmental policy options for conserving gasoline and improving air quality on families that own and operate cars in the United States. Specifically, the study is concerned with the effect on income distribution of governmental policy options that may cause the costs of owning and operating a car to increase. The models were reported in 1977 and were sponsored by the National Science Foundation and the Federal Energy Administration. The second model, Household Expenditures on Automobile Ownership and Operation, which is described here, was developed to evaluate possible tactics that car owners of different income groups may use to reduce their auto ownership costs in an attempt to offset an increase in fuel cost. The authors conclude that a powerful means of offsetting travel cost increases for all income groups is to purchase a new car with better-than-average fuel economy.

The first model is described in 77-087A.

## SPONSOR

National Science Foundation
Washington, D.C. 20550

With additional Support from:
Federal Energy Administration
Washington, D.C. 20461

## AUTHOR

J.P. Stucker and T.F. Kirkwood
Rand Corporation
Santa Monica, Calif. 90406

## MODEL TYPE

Vehicle user costs/vehicle operating costs

## OBJECTIVE OF MODEL

The purposes of this model are to assess the effects of an increase in fuel price on households of different income groups and to evaluate possible tactics that owners may use to reduce their auto ownership costs in an attempt to offset a fuel cost increase. The tactics examined by the model are: (1) driving less, (2) using austere maintenance, (3) buying used cars, (4) eliminating second cars, and (5) buying new fuel-efficient cars.

## RELATIONSHIP TO OTHER MODELS

This model was developed in conjunction with the Consumption of Gasoline by Households Model (77-087A).

## HISTORICAL BACKGROUND

Past studies have arrived at estimates of auto ownership costs for all owners on the assumption of certain auto lifetimes and driving mileage. However, people in different income groups buy cars of different ages and drive them different amounts; and they may keep their cars in different states of repairs and carry different levels of insurance. This model addresses itself to these differences in ownership practices by different income groups.

## ASSUMPTIONS

The estimates of the number of miles each car is driven assume that the average second-hand car is driven less as it gets older. However, once a car is purchased, it is assumed to be driven the same distance each year, as determined by the income groups and age of the vehicle, for as long as the car is kept.

## STRUCTURE

The annual cost of ownership is given by:

$$A_t = P_t - P_{t+1} + r\,(P_t) + \frac{M}{y} + I + \frac{MC}{y(mpg)} + 30.1$$

where:

$A_t$ = annual ownership cost (dollars) of one auto in year t

$P_t$ = value of car at beginning of year t

$P_{t+1}$ = value of car at end of year t

M = total maintenance cost for y years

I = annual insurance cost

C = cost of gasoline per gallon

r = interest rate = 7%

y = years car is owned

30.1 = national average annual cost of registration and license

mpg = car miles per gallon

The depreciation and maintenance costs are estimated for new and used car purchases for each income group. These two estimates are combined by weighting them in accordance with the fraction of new and used cars that each income group purchases.

## MODEL CONSTRUCTION

New and used car prices were obtained from NADA Offices Used Car Guide, December 1970 and 1974.

Maintenance cost figures were based on Highway Research Board, Running Costs of Motor Vehicles Affected by Road Design and Traffic, National Cooperative Highway Research Program, Report III, Washington, D.C., 1971; also Consumer Reports, 1974.

Insurance costs are based on Consumer Reports, 1970.

## DATA USED IN RUNNING MODEL

The right-hand-side variables of the equation for auto ownership cost must be specified for various income groups.

## DOCUMENTATION

J.P. Stucker and T.F. Kirkwood, The Economic Impact of Automobile Travel Cost Increases on Households, R-1842-NSF/FEA, The Rand Corporation, July 1977.

# MODEL OF TRAFFIC NOISE

A Model of Traffic Noise was developed by Bolt, Baranek, and Newman under the sponsorship of the American Association of State Highway and Transportation Officials and the Federal Highway Administration in 1976. It is intended for use by highway planners in designing roads to meet noise level design standards in adjacent land use areas.

## SPONSOR

American Association of State Highway and Transportation Officials
341 National Press Building
Washington, D.C. 20045

Federal Highway Administration
U.S. Department of Transportation
Washington, D.C. 20590

## AUTHOR

B. Andrew Kugler, Daniel E. Cummins, and William T. Galloway
Bolt, Baranek and Newman
Los Angeles, Calif.

## MODEL TYPE

Noise pollution

## OBJECTIVE OF MODEL

This model predicts the noise level produced by highway traffic at selected observation points, given the volume and speed of traffic, the distance to the roadway from the observation point, and the physical configuration of the road and the surrounding landscape. A method is described by which highway planners can use the model to design roads and sound barriers or choose the alignment of new roads, so as to meet noise level standards for abutting land uses. The described method is intended to help highway planners comply with federal and state noise control legislation.

## RELATIONSHIP TO OTHER MODELS

The user is advised to use first a "short method" involving hand calculations and nomographs to obtain gross approximations and identify potential problem areas. Then the "complete method" is used, involving the computer model and precise data input, to evaluate alternative road design features.

HISTORICAL BACKGROUND

This study is the fourth in a series of highway noise research studies carried out under the National Cooperative Highway Research Program.

ASSUMPTIONS

The noise emissions levels are assumed to be different for three classes of vehicles: automobiles, medium trucks, and heavy trucks. These values are derived from complex engineering studies of noise sources, including engines, exhaust systems, tires, etc.

VALIDATION

No validation efforts are presented in the report of the model.

LIMITATIONS AND BENEFITS

The model allows for a large variety of variables that may affect noise diffusion, and thus requires a complex set of input data to be prepared. The model deals primarily with changes to the physical environment rather than with changes to motor vehicles which may be made to minimize noise pollution. However, some discussion is devoted to changes in motor vehicles which may be made, but these potential alterations are not included in the model.

STRUCTURE

The model predicts $L_{10}$, the sound level in decibels that is exceeded 10% of the time, produced by an infinite line source. Adjustments are made for finite attenuated line sources, angle from source, road width variations, grades, curves, pavement type, imbalanced flow, differences in directional average speed, barriers, and differences in directional flow elevation. Those elements of the proposed roadway that are excessively noisy are identified, as are the shielding elements required at that point to reduce noise levels to the design goal.

MODEL CONSTRUCTION

This is a physical relationships model using a computational algorithm, with some adjustment to bring it in line with observed results.

DATA USED IN RUNNING MODEL

To run the model, the user must identify observer locations, roadway length and width, division into elements due to alignment, traffic characteristics, ramps, shielding, and barriers.

## DOCUMENTATION

Bolt, Baranek and Newman, Highway Noise-Generation and Control, National Cooperative Highway Research Program Report 173, Transportation Research Board, Washington, D.C., 1976.

Bolt, Baranek and Newman, Highway Noise-A Design Guide for Prediction and Control, National Cooperative Highway Research Program Report 174, Transportation Research Board, Washington, D.C., 1976.

## COMPUTER REQUIREMENTS

National Cooperative Highway Research Program Report 174 is a step by step guide to using the computer model and the "short method." The complete program, written in FORTRAN, is included.

# DOT MODEL (VEHSIM)

A model of auto fuel economy, performance, and emissions, sometimes referred to as VEHSIM, was prepared at the U.S. Department of Transportation (DOT) in 1976. It simulates the performance of the auto engine, and may be used to predict performance, fuel economy, and emissions, given changes in engine specifications. It was used by DOT in the Motor Vehicle Goals Beyond 1980 Study.

## SPONSOR

U.S. Department of Transportation
Washington, D.C. 20590

## AUTHOR

A.C. Malliaris, H. Gould, T. Trella, E. Withjack
U.S. Department of Transportation
Washington, D.C. 20590

## MODEL TYPE

Fuel economy, emissions, vehicle operating performance

## OBJECTIVE OF MODEL

This model simulates the physical performance of the automobile engine, including its fuel economy, emissions, and acceleration rate, given its weight, the number of cylinders, and type of transmission.

## RELATIONSHIP TO OTHER MODELS

This model has capabilities similar to those of GPSIM (72-017).

## HISTORICAL BACKGROUND

An earlier version of this model was called VEHSIM.

## ASSUMPTIONS

The operation of the internal combustion engine is simulated with the engine manifold system treated as a sequence of many small but finite control volumes, each obeying the field form of conservation equations. This is a new approach in the treatment of engine breathing dynamics.

## VALIDATION

Results of the simulation are compared with Environmental Protection Agency fuel-economy and emissions measurements. Fuel economy is predicted within five to ten percent of actual measurements, $NO_x$ is within twenty-five percent, while there are substantial errors for CO and HC.

## LIMITATIONS AND BENEFITS

The model is stronger in producing relative rather than absolute results. The resolution of individual applications is found to be limited by substantial uncertainties in inputs such as combustion initiation and duration, and in the estimation of the residual fraction in the cylinder.

## STRUCTURE

This is an engineering model whose computations rely on analytically tractable aspects of auto operation and on extensive engineering test data of pivotal components. Equations involve force, acceleration, torque, engine speed, and vehicle load.

## MODEL CONSTRUCTION

Detailed engineering test data regarding components and parameters of 1975 autos were used to build the model.

## DATA USED IN RUNNING MODEL

Engine performance maps, including information on engine loads and speeds, specific fuel consumption, WOT performance, torque converter characteristics, gear and axle ratios, shift logics, rotating inertias, tire parameters and accessory loads are inputs to the simulation.

## DOCUMENTATION

A.C. Malliaris, E. Withjack, and H. Gould, <u>Simulated Sensitivities of Auto Fuel Economy, Performance and Emissions</u>, Society of Automotive Engineers Paper No. 760157.

A.C. Malliaris, T. Trella, and H. Gould, <u>Engine Cycle Simulations and Comparisons to Real Engine Performance</u>, Society of Automotive Engineers Paper No. 760155.

# DIFKIN PHOTOCHEMICAL POLLUTION DIFFUSION MODEL

The DIFKIN Photochemical Pollution Diffusion Model was developed by the General Research Corporation in 1976 under the sponsorship of the Environmental Protection Agency and the Department of Health, Education, and Welfare. It is intended for use by transportation planners in simulating the effects of a single segment of a transportation plan on the air quality of a metropolitan region.

## SPONSOR

National Air Pollution Control Administration
Department of Health, Education and Welfare
330 Independence Avenue SW
Washington, D.C. 20201

Coordinating Research Council
30 Rockefeller Plaza
New York, N.Y. 10020

Air Pollution Control Office
Environmental Protection Agency
401 M Street SW
Washington, D.C. 20460

## AUTHOR

A. Eschenroeder, J. Martinez, and R. Nordsieck
General Research Corporation
Santa Barbara, Calif. 93105

## MODEL TYPE

Air pollution/air quality

## OBJECTIVE OF MODEL

This model simulates the transport, chemical reactions, and diffusion of pollutants in the region surrounding a highway. It is intended for use by transportation planners.

## RELATIONSHIP TO OTHER MODELS

The DIFKIN Model is intended for use in project level comparisons--for testing the effects of a single segment of a local transportation plan. Other models would be used on a system level for simulating the effects of an entire transportation plan on the region.

## HISTORICAL BACKGROUND

The authors began work on this subject in the late 1960s.

## ASSUMPTIONS

This is a Lagrangian model that simulates a column of air travelling with the wind through a grid system in a metropolitan area.

## VALIDATION

Sensitivity analysis of the model was done. It was found that the model was most sensitive to initial pollutant concentrations, reaction rate constants, and diffusivity coefficients.

## LIMITATIONS AND BENEFITS

The model is not applicable for convergent or divergent wind flow fields, where vertical wind shear is involved, or for multi-day simulations.

## STRUCTURE

A simplified mass continuity equation is solved for each vertical cell of the column of air as it moves along its trajectory. The mass concentration of the pollutant with respect to time, speed, and direction is calculated as a function of the vertical turbulent diffusion coefficient, the reaction (production/destruction) rate, and the source flux emission rate. The chemical module of the model contains sixteen chemical reaction equations.

## MODEL CONSTRUCTION

Chemical reaction and kinetic diffusion equations were derived by the authors based on earlier work by themselves and others.

## DATA USED IN RUNNING MODEL

Inversion base height, diffusivity coefficients, initial concentrations, and a trajectory must be input to the model.

## DOCUMENTATION

P.D. Allen, W.B. Crews, A.J. Ranzieri, and E.C. Shirley, Transportation Systems and Regional Air Quality--A DIFKIN Sensitivity Analysis, Office of Transportation Laboratory, California Department of Transportation, 1976.

A.Q. Eschenroeder and J.R. Martinez, "Concepts and Applications of Photochemical Smog Models," in Advances in Chemistry Series 113, 1972, pp. 101-168.

COMPUTER REQUIREMENTS

A run of the program on an IBM 370 costs about twenty dollars. A sample of data cards input to the program is provided in the Allen et al. report.

76-092

# CONSUMER CREDIT AND CONSUMER DEMAND FOR AUTOMOBILES

A model of Consumer Credit and Consumer Demand for Automobiles was prepared at the University of Lowell Environmental Law Institute and appeared in The Journal of Finance in March 1976. The objective of the model is to provide an alternative measure of consumer installment credit contract length and to test the explanatory power of the new variable as a determinant of automobile demand.

## AUTHOR

David B. Eastwood
University of Lowell
Lowell, Mass. 01854

Robert Anderson
Environmental Law Institute
1346 Connecticut Ave. NW, Suite 614
Washington, D.C. 20036

## MODEL TYPE

Automobile demand

## OBJECTIVE OF MODEL

The objective of the model is to develop an alternative estimation procedure for contract length of consumer installment credit and to test the explanatory power of the new series as a determinant of automobile demand.

## RELATIONSHIP TO OTHER MODELS

There is no direct operating relationship to other models.

## HISTORICAL BACKGROUND

Previous studies of the role of consumer installment credit have used the availability of credit as a determinant of consumer durable expenditure. The definition of average contract length used in these studies suffers from two deficiencies: contract length is biased when the volume of credit extended changes, and it is derived from an average of all outstanding credit rather than from a measure of current credit conditions. This model is designed to remedy these two deficiencies.

## VALIDATION

The statistical properties of the equation over the fit period are analyzed. No post-sample evaluations are conducted.

## LIMITATIONS AND BENEFITS

The analysis is restricted to only one credit term, length of contract. No aggregate time series data are available for all three credit terms: the downpayment percent, the finance charge, and the length of contract. Since the authors choose to deal only with the length of contract, it must be assumed that the average maturity is a measure of ease of credit in general.

A new method of estimating one of the terms of credit--length of contract--is developed. Theoretically it avoids the problem of the systematic bias contained in the average maturity for all outstanding debt. The new series is also desirable because it reflects current credit conditions, not a weighted average of current and existing loans.

## STRUCTURE

The basic stock adjustment model of auto demand that was estimated is as follows:

$$S^* = a + b\,(Y) + c\,(Pd) + f\,(N^*)$$

where:

$S^*$ = desired stock of autos

$Y$ = real disposable income

$Pd$ = relative price of autos

$N^*$ = average maturity of new debt

The following relationships are used:

$$Cd = S - S_{-1} + D$$

$$S - S_{-1} = T(S^* - S_{-1})$$

$$D = e_1\,(Cd) + e_2\,(S_{-1})$$

where:

$S$ = actual stock of cars

$Cd$ = consumer durable expenditure for autos and parts

$T$ = adjustment coefficient

$D$ = replacement expenditure

$e_1$ = depreciation of current period expenditure

$e_2$ = depreciation of existing stock

The following basic stock adjustment equation is obtained:

$$Cd = T(S^* - S_{-1}) + e_1\,(Cd) + e_2\,(S_{-1})$$

The estimated results in the model report indicate that the new contract length series N*, performs better in the model than the traditional contract length series which measures average maturity of all outstanding credit.

## MODEL CONSTRUCTION

The model is not intended to be an operational simulation model to be used for ex-ante forecasting and policy analysis. The data sources used in building the model are not well documented in the model report.

## DATA USED IN RUNNING MODEL

Values for all the exogenous variables in the model are necessary to generate predictions for auto demand.

## DOCUMENTATION

David B. Eastwood and Robert Anderson, "Consumer Credit and Consumer Demand for Automobiles," The Journal of Finance, Vol. XXXI, No. 1, March 1976, pp. 113-123.

# INDEXES

## AUTHOR INDEX

The authors of the models in this index are listed alphabetically, personal authors in Part 1 and organizational authors in Part 2. The accession code numbers for all the models in this inventory by each author follow the author's name. In the case of joint authorship, each author is listed separately. Not all models have both personal and organizational authors, and, therefore, not all models appear on both lists.

## SPONSOR INDEX

The sponsors of the models in this inventory are listed alphabetically. The accession numbers of all the listed models funded by the sponsor are entered after each sponsor's name. In the case of more than one sponsor for a model, each sponsor is listed separately.

## MODEL TYPE INDEX

The accession numbers of all models of each type are listed following the designation of model type. The model types are not mutually exclusive, and, therefore, a model may be listed under several types.

## MODEL NAME INDEX

The titles or commonly accepted name of each of the models are listed in alphabetical order, with the accession code number following each title.

## ACCESSION NUMBER INDEX

Each model is listed in order of accession number. The accession number, model name, authors, model types, and sponsors of each model are given. The meaning of abbreviations used in this index may be found in the list on the following page.

Once a model has been identified by accession number using these indexes, the summary describing it may be located in this report either by using the accession numbers in the upper corners of the pages, or by finding the page on which it is located by referring to the Table of Contents.

## ABBREVIATIONS USED IN ACCESSION NUMBER INDEX

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| CEQ | Council on Environmental Quality |
| CRC | Coordinating Research Council |
| DOE or USDOE | Department of Energy |
| DOT or USDOT | Department of Transportation |
| EPA | Environmental Protection Agency |
| FEA | Federal Energy Administration |
| FHWA | Federal Highway Administration |
| GMC | General Motors Corporation |
| HEW | Department of Health, Education, and Welfare |
| MVMA | Motor Vehicle Manufacturers Association |
| NHTSA | National Highway Traffic Safety Administration |
| NSF | National Science Foundation |
| RANN | Research Applied to National Needs |
| TRB | Transportation Research Board |
| TSC | Transportation Systems Center |
| UMTA | Urban Mass Transportation Administration |

| SPONSOR | ACCESSION NUMBER |
|---|---|
| American Association of State Highway and Transportation Officials | 76-089 |
| Coordinating Research Council | 76-091 |
| Council of Environmental Quality | 74-002, 73-040 |
| Environmental Development Agency, San Diego County | 73-078, 73-082 |
| Environmental Protection Agency | 73-040, 76-076, 73-082, 76-091 |
| Federal Energy Administration | 75-003A,B,C, 76-016, 75-058, 76-066, 77-087A,B |
| Ford Foundation | 73-010 |
| Ford Motor Company | 58-033 |
| General Motors Corporation | 72-017 |
| Motor Vehicle Manufacturers Association | 75-057, 75-072, 75-073 |
| National Research Council of Canada | 76-069 |
| National Science Foundation | 74-001A,B,C, 75-027A,B, 75-052, 77-056, 75-058, 76-062, 76-086 77-087A,B |
| Transportation Research Board | 75-052, 76-068 |
| Urban Mass Transportation Administration | 75-071 |
| U.S. Department of Health, Education and Welfare, National Air Pollution Control Administration | 76-091 |
| U.S. Dept. of Labor, Bureau of International Labor Affairs | 76-025 |
| U.S. Department of Transportation, Federal Highway Administration | 76-066, 75-071, 76-084, 76-089 |
| U.S. Department of Transportation, National Highway Safety Bureau (now National Highway Traffic Safety Administration) | 69-009 |

MODEL TYPE INDEX

ACCESSION NUMBER INDEX

| ACC. NO. | NAME | AUTHOR | MODEL TYPE | SPONSOR |
|---|---|---|---|---|
| 74-001A | Generalized Automobile Design Model | Rand Corporation | Automobile Design | NSF |
| 74-001B | Automobile Fleet Mix Model | Rand Corporation | Fleet Size | NSF |
| 74-001C | New Car Sales/Automobile Ownership Vehicle Miles Traveled (NAV) Model | Rand Corporation | Automobile Demand, Fleet Size, VMT | NSF |
| 74-002A | New Passenger Car Sales and Market Shares | Chase Econometric Associates | Automobile Demand, Market Shares | CEQ |
| 74-002B | Gasoline Consumption Model | Chase Econometric Associates | Fleet Size, Scrappage, VMT, Fuel Consumption | CEQ |
| 75-003A | Technology Model | Energy and Environmental Analysis Inc. (EEA) | Fuel Economy, Weight, Pricing | FEA |
| 75-003B | Economics Submodel | EEA | Automobile Demand, Market Share, VMT, Fuel Consumption | FEA |
| 75-003C | Emissions Submodel | EEA | Emissions | FEA |
| 75-004A | Auto Simulation Model of Project Independence Evaluation System (PIES) | FEA | Fuel Economy, Energy Consumption, VMT, Fuel Consumption, Auto Demand, Market Share | FEA |
| 75-004B | World Energy Model (PIES) | FEA | Fuel Economy, Energy Consumption, Vehicle Miles Traveled, Fuel Consumption, Auto Demand, Market Share | FEA |
| 74-005 | Modified Rollback Program | EPA | Air Quality/Air Pollution | EPA |
| 75-006 | Highway Fuel Consumption Model | TSC, Gould, Malliaris | Vehicle Miles Traveled, Fuel Consumption, Fleet Size | DOT |
| 76-007 | Auto Fleet Submodel | Kentron Hawaii, Ltd., Rodi | Fuel Economy, Auto Demand, Market Share, VMT, Scrappage, Emissions | TSC |
| 73-010 | User Cost Approach to New Auto Purchases | Pomona College, Wykoff | Auto Demand | Ford Foundation |
| 75-011 | Aggregate Auto Miles Traveled | TSC, Ward, Horan | Vehicle Miles Traveled | TSC |
| 75-013 | Econometric Model of New Car Sales | TSC, Meilman | Automobile Demand | TSC |

| ACC. NO. | NAME | AUTHOR | MODEL TYPE | SPONSOR |
|---|---|---|---|---|
| 76-016 | Automobile Sector Forecasting Model (Faucett Model) | Jack Faucett Assoc., Inc. | Automobile Demand, VMT, Scrappage, Market Share, Fuel Consumption | FEA |
| 72-017 | General Purpose Auto Vehicle Performance and Economy Simulator (GPSIM) | General Motors Corp., Waters | Vehicle Operating Performance, Auto Design | General Motors Corp. |
| 75-019 | Policy Search Model for Evaluating Future National Transportation Strategies | Chicago Transit Authority, Northwestern University, Bernard, Schofer | Vehicle Miles Traveled, Modal Split, Energy Consumption | Chicago Transit Authority |
| 76-022A | VMT Submodel of Integrated Fleet Model | Environmental Impact Center (EIC) Corp. | Vehicle Miles Traveled | TSC |
| 76-022B | New Car Sales Submodel of Integrated Fleet Model | EIC Corp. | Automobile Demand | TSC |
| 76-022C | Fleet Submodel of Integrated Fleet Model | EIC Corp. | Fleet Size | TSC |
| 74-023 | Automotive Propulsion Simulator (APS) | University of Wisconsin, Beachley, Frank | Vehicle Operating Performance, Fuel Economy, Emissions, Air Pollution/Air Quality | DOT |
| 76-024A | Materials and Energy Resource Accounting Model (ARAM) | Draper Lab | Vehicle Manufacturing Resource Utilization, Energy Consumption | TSC |
| 76-024B | Capital and Labor Resource Accounting Model (INRAM) | Draper Lab | Vehicle Manufacturing Resource Utilization | TSC |
| 76-025 | CRA Hedonic Market Share Model | Charles River Associates, Inc. | Pricing, Market Share, Vehicle Manufacturing Resource Utilization, Auto Demand | Department of Labor |
| 75-027A | SPECULATER: Land, Agriculture, Transportation, and Energy | University of California at Davis, Young et al. | Energy Consumption, Vehicle Miles Traveled, Vehicle User Costs, Modal Split | NSF, RANN |
| 75-027B | SAM: Sacramento Area Model | University of California at Davis, Young et al. | Energy Consumption, Vehicle Miles Traveled, Vehicle User Costs, Modal Split | NSF, RANN |
| 75-028 | Transportation and Airshed Simulation Model (TASSIM) | Harvard University, Fauth, Kroch | Air Pollution/Air Quality | DOT |

# ACCESSION NUMBER INDEX

| ACC. NO. | NAME | AUTHOR | MODEL TYPE | SPONSOR |
|---|---|---|---|---|
| 75-029 | Consumer Demand for Cars in the USA | Cambridge University, Smith | Automobile Demand | |
| 77-030 | Engineering Model of Future Motor Vehicles (EMFMV) | Volkswagon, Danckert et al. | Automobile Design, Vehicle Operating Performance | NHTSA |
| 58-033 | Demand for New Autos in the U.S. 1929-1956 | University of Michigan, Suits | Automobile Demand | Ford Motor Co. |
| 77-035 | Model of Auto Industry Response to Government Regulations | Pugh-Roberts Associates, Inc., Cooper et al. | Industrial Financial Performance, Auto Demand, Market Share, Scrappage, Pricing | TSC |
| 75-036 | TRANS-Urban Model (Transportation Resource Allocation Study) | DOT, Weiner | VMT, Modal Split, Vehicle User Costs, Accidents, Emissions, Fuel Consumption | DOT |
| 74-037A | Gasoline Demand Model | TSC, Anderson | Fuel Consumption | TSC |
| 74-037B | Auto Choice by Class of Car: Aggregate State Data | TSC, Chamberlain | Market Shares | TSC |
| 74-037C | Highway Fuel Consumption Model | TSC, Pollard | Fuel Consumption | TSC |
| 74-039A | Market Share Model | TSC, Schuessler, Smith | Market Share | TSC |
| 74-039B | Aggregate Sales Model | TSC, Schuessler, Smith | Automobile Demand | TSC |
| 74-039C | Vehicle-Miles Model | TSC, Schuessler, Smith | Vehicle Miles Traveled | TSC |
| 73-040 | Quarterly Demand for Gasoline Model | Data Resources, Inc. | Fuel Consumption | EPA, CEQ |
| 73-041 | Annual Model of Passenger Car Gas Consumption in the U.S. | TSC, Chamberlain | Fuel Consumption | TSC |
| 73-043 | U.S. Truck and Bus Population Model | Michigan Tech. Univ., Tingley | Trucks, Emissions, Fuel Consumption, VMT, Scrappage | |
| 77-046 | Wharton EFA Automobile Demand Model | Wharton Econometric Forecasting Associates, Inc., Schink, Loxley | Auto Demand, Scrappage, Market Share, Vehicle Miles Traveled, Pricing | TSC |
| 76-047 | Transportation Safety Analysis Model (Highway Submodel) | Center for Environment and Man, Inc., Joksch | Accidents | TSC |

| ACC. NO. | NAME | AUTHOR | MODEL TYPE | SPONSOR |
|---|---|---|---|---|
| 74-048 | Private and Commercial Demand for Gasoline | Michigan State University, Ramsey, et al. | Fuel Consumption | |
| 71-049 | Infrequent Purchase Behavior in a Stock Adjustment Model | University of Toronto, Westin | Automobile Demand | |
| 75-052 | Gasoline Use Model | Urban Institute, McGillivray | Fuel Consumption | Transportation Research Board, NSF |
| 77-056 | Response to Mandates for Increased Fuel Economy | Rand Corp., Stucker, et al. | Auto Demand, Fuel Economy, Pricing | NSF |
| 75-057 | Quantification of Transportation Noise | Wyle Lab., Rackl, Sutherland, Swing | Noise Pollution | MVMA |
| 75-058 | Econometric Models of the Demand for Motor Fuel | Rand Corp., Enns, Burright | Fuel Economy, VMT, Auto Demand, Fuel Consumption | NSF, FEA |
| 76-061 | Elasticities of Demand for New Autos | GMC, Gallasch | Auto Demand | GMC |
| 76-062 | Decision Analysis of Auto Emission Control | Stanford U., Judd | Emissions, Economic Impact | NSF |
| 70-063 | Motor Vehicle/Highway Noise Model | Serendipity, Inc. | Noise Pollution | DOT, Office of Noise Abatement |
| 77-064 | Demand for Autos in the U.S. | U. of Mich., Luckey | VMT, Pricing, Auto Demand, Market Share | |
| 75-065 | Manufacturing Assessment System | Rath and Strong, Inc., Lindgren, Fitzgibbons | Pricing, Vehicle Manufacturing Resource Utilization, Auto Design | TSC |
| 76-066 | Urban Traffic Control System-Program I Simulation Model | Honeywell, Inc. | Fuel Economy | FEA, FHWA |
| 77-067 | Auto Fleet Fuel Consumption Model (FUEL) | TSC, Horton | Fuel Consumption | TSC |
| 76-068 | Urban Area Auto Emissions According to Trip Type | EPA, U. of Alaska, Horowitz, Pernela | Emissions | TRB |
| 76-069 | Noise Annoyance Impact Algorithm | McMaster Univ., Hall, Allen | Noise Pollution | National Research Council of Canada |
| 76-070 | AIRPOL-4 | Va. Hwy. and Trans. Research Council, Carpenter, Clemena | Air Pollution/Air Quality | Va. Dept. of Hwys. and Trans. |

| ACC. NO. | NAME | AUTHOR | MODEL TYPE | SPONSOR |
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| 75-071 | Manual Model to Predict Highway Related CO Concentrations | Southeast Mich. Council of Governments, Doctor | Air Pollution/Air Quality, Emissions | USDOT, UMTA, FHWA |
| 75-072 | Light Duty and Control Cost Simulation Model | Mathematica | Air Pollution/Air Quality, Emissions, Vehicle Operating Costs | MVMA |
| 75-073 | Automobile and Gasoline Demand Model | U. of Arizona, Data Resources, Inc., Taylor, Verleger, Hirtzel | Pricing, Auto Demand, Market Share, Fuel Fuel Consumption | MVMA |
| 77-074 | Automobile Demand Equations | U. of Washington, Hess | Auto Demand | |
| 72-075 | Estimating Auto Emissions of Alternative Transp. Systems | Metro. Wash. Council of Governments, Berwager, Wickstrom | Emissions, VMT, Auto Demand, Air Pollutionn/Air Quality | USDOT |
| 76-076 | MATHAIR | Mathtech, Inc. | Emissions, VMT, Auto Demand, Modal Split, Air Pollution/Air Quality | EPA |
| 76-080 | Pricing in the Auto Industry: A Simple Econometric Model | Va. Commonwealth U., Mary Washington College, Hoffer, Marchand, Albertine | Pricing | |
| 73-082 | Motor Vehicle Emission and Cost Model (MOVEC) | Rand Corp., Mikolowsky | Air Quality, Emissions, Economic Impact, Vehicle User/Operating Costs | County of San Diego, Calif., EPA |
| 76-084 | CALINE-2 Calif. Line Source Dispersion Model | Calif. Dept. of Trans., Ward et al. | Air Pollution/Air Quality | FHWA |
| 77-085 | Dynamic Model of the U.S. Auto Fleet | SIC, Inc., Rabe | Fleet Size | TSC |
| 77-086 | Determinants of Scrapping Rates for Postwar Vintage Autos | Univ. of Washington, Parks | Scrappage | NSF |
| 77-087A | Consumption of Gasoline by Households | Rand, Stucker Kirdwood | Vehicle Miles Traveled, Fuel Consumption | NSF, FEA |
| 77-087B | Household Expenditures on Auto Ownership and Operation | Rand, Stucker, Kirkwood | Vehicle User Costs/ Vehicle Operating Costs | NSF, FEA |
| 76-089 | Model of Traffic Noise | Bolt, Baranek and Newman, Fosler et al. | Noise Pollution | AASHTO, FHWA |

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| 76-090 | DOT Model (VEHSIM) | USDOT, Malliaris et al. | Fuel Economy, Emissions, Vehicle Operating Performance | USDOT |
| 76-091 | DIFKIN Photochemical Pollution Diffusion | General Research Corp., Eschenroeder et al. | Air Pollution/Air Quality | HEW, CRC, EPA |
| 76-092 | Consumer Credit and Consumer Demand for Autos | U. of Lowell, Environ. Law Inst., Eastwood, Anderson | Auto Demand | |