THE STAR METHODOLOGY FOR SHORT-HAUL TRANSPORTATION: TRANSPORTATION SYSTEM IMPACT ASSESSMENT

PREPARED FOR THE U.S. DEPARTMENT OF TRANSPORTATION

L. G. CHESLER
B. F. GOELLER

R-1359-DOT
DECEMBER 1973

25th
Year

Rand
SANTA MONICA, CA. 90406

THE STAR METHODOLOGY FOR SHORT-HAUL TRANSPORTATION: TRANSPORTATION SYSTEM IMPACT ASSESSMENT

PREPARED FOR THE U.S. DEPARTMENT OF TRANSPORTATION

L. G. CHESLER AND B. F. GOELLER

R-1359-DOT

DECEMBER 1973

01936

PREFACE

This is one of a series of nine reports describing The Rand Corporation's work for the Department of Transportation (DOT) on the STAR study, performed under contract DOT-TSC-363. STAR is an acronym for a project called Short-haul Transportation Analysis for Research and Development which was directed by the DOT Office of Research and Development and, in its early phases, involved several other contractors.

Undertaken in 1971, the study is intended to provide guidance for multimodal research and development policy within DOT to answer such questions as: What are the relative costs and benefits of R&D investments in new air and ground passenger systems? What are the more attractive features of such systems? What problems do the systems pose and what do the problems imply for R&D program emphasis? What are the tradeoffs among service, costs, and environmental impacts, and what are the distributional effects of the various tradeoffs?

In response to this requirement and as part of the overall STAR study, The Rand Corporation initiated the development of a systems impact assessment methodology to analyze the full regional impacts of short-haul transportation systems. Rand's work comprised a two-part effort: STAR I, documented in an earlier unpublished note; and STAR II, described in this series. Although other organizations have at different times been involved in the project, when we use the word "STAR," we refer to work done by Rand.

While various aspects of planning for transportation systems have been analyzed, until recently most studies dealt either with the technological aspects of developing hardware or the direct benefits and costs of proposed systems to users and operators. Analysis of the broader social, economic, and environmental impacts of proposed transportation systems has been limited. Yet, as Congress, the Office of Management and Budget, and various citizen groups have suggested, such analysis is essential to select systems that will best meet future needs. Reduced travel time, lower fares, and increased accessibility must be weighed against such factors as noise, air pollution, and

energy consumption. In addition, explicit consideration should be given to the broader impacts on such things as land use, employment, income, and the differential effects on various social groups.

The Rand methodology was developed to help analyze this wide range of impacts for alternative transportation systems, thus providing guidance for R&D policy decisions and, ultimately, for broader policy, investment, planning, and operational decisions. The publications deriving from this effort are intended for transportation planners and decisionmakers interested in using the STAR approach and methodology or both in their own regional studies of short-haul transportation. The reports also will interest policy analysts and planners in related fields who are grappling with similar problems of R&D policy analysis and impact assessment evaluation.

Specific procedures for using the STAR methodology and its supporting computer programs are outlined in handbook fashion in the following reports. The present report is a summary volume; each of the remaining eight, available upon request, details a specific aspect of the study, as indicated by its title. Agencies or organizations interested in fully utilizing the STAR methodology will find it essential to refer to the eight supporting reports.

R-1359-DOT   The Star Methodology for Short-Haul Transportation: Transportation System Impact Assessment

R-1359/1-DOT   The Star Methodology for Short-Haul Transportation: Regional Description

R-1359/2-DOT   The Star Methodology for Short-Haul Transportation: Demand Prediction--Approach and Calibration

R-1359/3-DOT   The Star Methodology for Short-Haul Transportation: Transportation System Description

R-1359/4-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Service and Financial Impacts Using the Supply-Demand Program

R-1359/5-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Economic Impacts from System Construction

R-1359/6-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Community Environmental and Social Impacts

R-1359/7-DOT   The Star Methodology for Short-Haul Transportation: Description of Census Data Programs

R-1359/8-DOT   The Star Methodology for Short-Haul Transportation: Description of Noise Impact Assessment Programs

Rand's contract required only that the material in the supporting reports, R-1359/1 through R-1359/8, be provided to the Department of Transportation as Working Notes, solely for DOT use; it did not provide resources for publication and widespread distribution. In answer to considerable outside interest, Rand has used its own resources to expand and refine the auxiliary volumes and to publish them as addenda to the project's summary report. Because of limited funds, the addenda have received a minimal, less formal editorial treatment than that usually given Rand reports.

SUMMARY

This is a summary volume of a series of nine reports documenting the STAR methodology developed by Rand for performing R&D policy analysis studies of short-haul (50 to 500 miles) passenger transportation systems. The methodology, which allows comparison of air and ground modes, was developed to help analyze the following range of impacts for alternative transportation systems.

- o *Service impacts.* Door-to-door time and cost, passenger volumes, passengers diverted from existing facilities.
- o *Financial impacts.* System investments, operator profit and taxes, operating costs, annual subsidy required.
- o *Economic impacts.* Changes in regional income and employment as a result of system construction.
- o *Community impacts.* The amount of land taken, the number of households displaced, the number of households exposed to excessive noise, the amount of energy consumed, the changes in the amount of air pollution emissions.
- o *Social impacts.* The distribution of benefits and disbenefits by social group, including the fraction of travelers in high-, medium-, and low-income groups; the proportion of business and nonbusiness travelers; the fraction of those exposed to excessive noise by race and income group.

We have applied the methodology to analyses of innovative short-haul systems in the California Corridor, which extends from San Diego to Sacramento, excluding the sparsely populated territory near the eastern border and near the western coastline above Santa Barbara and below Monterey. Throughout the STAR reports, examples from California Corridor analyses are used to illustrate use of the methodology, which can be applied to the region a planner is interested in.

Rand developed the STAR methodology within the framework of the *System Impact Assessment* approach to systems evaluation. In this

approach, impacts are presented in terms of their natural, physical units, rather than being converted to some other scale such as dollars or an abstract measure of worth. For example, under this definition noise impacts were measured by the number of households receiving excessive noise, and pollution by emission levels. Real costs and revenues were measured in terms of dollars. Also, some impacts can be represented in qualitative terms, where appropriate. For example, when a historical landmark might be destroyed, it could be identified by name and the damage described rather than attempting to estimate the costs to national culture.

In a typical study, the planner using the STAR methodology defines and describes a set of alternative transportation systems he wishes to evaluate, as well as the region in which these systems are to operate and for which the selected set of impacts will be analyzed. A particular mix of transportation technology modes (e.g., auto access and vertical takeoff and landing aircraft line haul) viewed in the context of a particular regional forecast defines a specific *case* for analysis (e.g., 1985 conventional takeoff and landing aircraft and auto access evaluated in the California Corridor with competing auto and bus modes, assuming 1970 population). The cases and the related set of impacts form the basis for the analysis. Impacts are predicted using the procedures and computer programs briefly described in this volume and described in detail in the auxiliary reports.

To facilitate comparisons required for the many impacts, Rand developed a presentation technique called the colored scorecard. It provides the decisionmaker with an effective picture of the relative advantages and disadvantages of alternative systems being compared. The technique presents a column of impacts (each one in its own natural units) for each alternative system being compared. Then, colors are added to indicate each system's ranking for a particular impact: green shows the best value, blue the next best value, orange an inferior value, and red the worst value. These colors are meant to show only the system rankings for a particular impact, not their exact performance; this is shown by the impact values themselves that are visible through the colors.

The scorecard allows the decisionmaker to assign each impact whatever relative weight he deems appropriate in his subjective deliberations. It allows him to see quickly and easily the relative strength and weakness of various systems, to consider impacts that cannot be expressed in quantifiable terms, and to change his weightings and note the effect that this would have on his choice of systems. It also is a useful tool for interaction with the public. This presentation technique has been favorably received by a variety of decisionmakers, ranging from federal transportation and environmental policymakers to state legislators and local planners.

This report has three sections. Section I presents the background of the STAR study at Rand. Section II presents an overview of STAR analysis procedures, and Sec. III discusses the contents of the other STAR volumes. Each of the other STAR reports details procedures for performing specific parts of the analysis process discussed in Sec. II. This report should be read before any of the others and, in general, should also be used as a guide for applying any of the STAR methods.

ACKNOWLEDGMENTS

CONTENTS

I. INTRODUCTION

BACKGROUND OF THE STAR STUDY

In 1971, the Short-haul[1] Transportation Analysis for Research and Development (STAR) study was undertaken to help provide guidance for multimodal research and development (R&D) policy within the Department of Transportation (DOT). For various air and high-speed ground systems, DOT was concerned with such questions as: What are the relative costs and benefits of R&D investments in new air and ground passenger systems? What are the more attractive features of such systems? What problems do the systems pose and what do the problems imply for R&D program emphasis? What are the tradeoffs among services, costs, and environmental impacts, and what are the distributional effects of the various tradeoffs?

The DOT Office of the Secretary was responsible for the study with the assistance from the modal administrations, NASA, and various other organizations. The study was directed by the DOT Office of R&D Policy and, in its early stages, involved several contractors with complementary approaches: Arthur D. Little, Inc., performed a macro analysis of service performance and demand, and considered institutional factors. Planning Research Corporation performed a micro analysis of break-even economics and environmental impacts, and their subcontractor, SYSTAN, contributed to synthesis and policy development. Booz-Allen Applied Research, Inc., provided a historical perspective and summarized current R&D efforts. The Rand Corporation performed a somewhat parallel study complementary to these, as described below.

THE STAR STUDY AT RAND[2]

Rand undertook a two-phase STAR program: STAR I, initiated in June 1971 and documented in an earlier unpublished note; and STAR

---

[1] Short-haul trips are those between 50 and 500 miles.

[2] Although other organizations were involved in the project, when STAR is used in this report it refers to work that Rand performed.

II, initiated in December of 1971 and described in this series of reports.

The STAR I study had three goals: (1) develop a system impact assessment approach to analyze the full regional impacts (both benefits and disbenefits) of short-haul transportation systems; (2) develop a prototype methodology to perform this assessment; and (3) test the feasibility of the methodology by applying it to alternative short-haul systems in the California Corridor region.[3]

STAR II had the following goals: (1) refine and considerably extend the prototype methodology developed in STAR I; (2) document and transfer the resultant methodology to DOT's Transportation Systems Center for its general use; and (3) where resources permit, perform additional analyses of the California Corridor using the completed methodology and additional modes.

This volume presents an overview of the STAR analysis procedure and provides a road map for using the STAR Methodology documentation contained in the addenda to the present report (R-1359/1-DOT through R-1359/8-DOT).

STAR DOCUMENTATION

STAR documentation was developed to provide a series of handbook reports to aid decisionmakers and planners interested in using the STAR methodology for conducting regional impact assessment studies of short-haul transportation systems. The documentation outlines specific procedures in handbook fashion for performing short-haul assessment studies. A representative selection of air and ground mode short-haul systems is used throughout to illustrate the methodology as it applies to the California Corridor. The documentation also describes the computer programs developed for use in performing STAR analysis procedures. In some cases, the computer program documentation transcends the specific STAR context where the programs have additional applications in other areas.

_____

[3]The California Corridor extends from San Diego to Sacramento, excluding the sparsely populated territory near the eastern border and near the western coastline above Santa Barbara and below Monterey.

The following reports describe the STAR II effort. This report is a summary volume; each of the remaining eight, available upon request, details a specific aspect of the study, as indicated by its title.

R-1359-DOT   The Star Methodology for Short-Haul Transportation: Transportation System Impact Assessment

R-1359/1-DOT   The Star Methodology for Short-Haul Transportation: Regional Description

R-1359/2-DOT   The Star Methodology for Short-Haul Transportation: Demand Prediction--Approach and Calibration

R-1359/3-DOT   The Star Methodology for Short-Haul Transportation: Transportation System Description

R-1359/4-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Service and Financial Impacts Using the Supply-Demand Program

R-1359/5-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Economic Impacts from System Construction

R-1359/6-DOT   The Star Methodology for Short-Haul Transportation: Prediction of Community Environmental and Social Impacts

R-1359/7-DOT   The Star Methodology for Short-Haul Transportation: Description of Census Data Programs

R-1359/8-DOT   The Star Methodology for Short-Haul Transportation: Description of Noise Impact Assessment Programs

The remainder of this volume discusses the need for a systems impact assessment methodology, presents an overview of the STAR methodology itself, and summarizes the contents of each STAR volume.

THE NEED FOR SYSTEMS IMPACT ASSESSMENT METHODOLOGY

Various aspects of planning for transportation systems have been studied. Until recently, most studies have concentrated on either the technological aspects of developing hardware or the direct benefits and costs of proposed systems to users and operators. Analysis of the

broader social, economic, and environmental impacts of proposed transportation systems has been limited. Yet, as Congress, the Office of Management and Budget, and various citizen groups have suggested, such analysis is essential to select transportation systems that will best meet future needs. Improved travel time, lower fares, and increased accessibility must be weighed against such factors as noise, air pollution, and energy consumption. In addition, the broader impacts on such things as land use, employment, income, and the differential effects on various social groups should be explicitly considered.

Accordingly, there is a clear need for a methodology that can analyze this wide range of impacts for alternative transportation systems, thus providing guidance for R&D policy decisions and, ultimately, for broader policy, investment, planning, and operational decisions.

Particularly for R&D policy decisions, which must precede other planning and implementation decisions, it is important to have a methodology that is relatively quick, easy, flexible, and economical. This makes it possible to do detailed analyses of the type described in this report on a short-term basis in response to the decisionmaker's needs as they arise; e.g., an analysis of the impacts of a prospective reduced takeoff and landing (RTOL) aircraft system could be accomplished in weeks and months (once the procedure is set up for a particular region) rather than years. If the methodology is sufficiently flexible, then it can predict and compare the impacts of radically different systems within a common framework: e.g., vertical and short takeoff and landing aircraft (V/STOL) as compared with tracked-air-cushion vehicle (TACV) impacts; or the impacts of engine noise abatement improvements can be compared with those from changes in operations (e.g., two-step approach) or from airport land redevelopment or acquisition. If the methodology is economical, then it becomes practical to compare many R&D alternatives under varying technical assumptions and regional circumstances. This can facilitate the screening of R&D alternatives to insure that no promising candidate is slighted because of limitations on analytic capability, and it can help develop understanding about what combinations of technology and policy variables make preferred systems.

To insure that it is policy relevant and useful, the systems impact assessment methodology discussed above should also be developed in the context of a specific policy problem and region. (It can later be adapted to other contexts.) A logical policy context for the initial development of such methodology is short-haul R&D policy; the aim is to help make and support better R&D decisions. Developed in this context, the methodology can build upon the Civil Aviation R&D Study (CARD) and the Northeast Corridor Study (NEC) results and contribute to DOT's evaluation of short-haul R&D candidates.

Accordingly, building on NEC and CARD, the STAR system impact assessment methodology was developed at Rand and applied to compare alternative short-haul R&D systems in the California Corridor. Short-haul vehicles were chosen with DOT from their CARD and the NECTP studies.[4] Those considered in STAR I were all passenger systems based upon 1985 technology: Conventional-takeoff-and-landing aircraft (CTOL), STOL, VTOL, TACV, auto-train (ATRN), as well as competitive automobile and bus.

In addition to these systems (except for ATRN), STAR II considers a reduced-takeoff-and-landing aircraft (RTOL) and an improved-passenger train (IPT) running on conventional rail track.

The California Corridor was chosen for the STAR studies partly because of its marked contrast to the Northeast Corridor; it provided an opportunity to compare the same vehicles in very different regions. The California Corridor has a more widely scattered population, separated by desert and mountain ranges instead of a relatively continuous population and even topography, and thus would provide a very different environment for high-speed ground systems. California also has numerous and well-distributed airports without the various air congestion problems plaguing airports in the Northeast Corridor; this would provide a different environment for air systems. California has very extensive and relatively uncongested highway systems (particularly for

---

[4]NECTP stands for the Northeast Corridor Transportation Project. That study region included the extensive transportation corridor going from Washington, D.C. to Boston and encompassing the surrounding fringe areas.

short-haul travel); this would provide a different environment for auto and bus systems. Another reason for choosing California was that, as a single-state corridor, transportation data would be relatively easier to gather than those for a multi-state corridor.

II. OVERVIEW OF THE STAR APPROACH

R&D POLICY ANALYSIS

The STAR methodology was designed to help the planner analyze a wide range of impacts for alternative transportation systems to provide guidance for R&D policy decisions and, ultimately, for broader policy investment, planning, and operational decisions. The planner is interested in comparing differences between systems, identifying system characteristics that result in desirable impacts while reducing undesirable effects, and evaluating the feasibility of promising innovative systems with regard to a full range of benefits and disbenefits.

This differs in emphasis from planning implementation studies which are concerned with the implementation and design of specific systems. The result of the implementation study is a blueprint for system construction and operation. At the time of the implementation study, many major decisions have already been made as to type of mode and performance requirements, characteristics of service to be provided, region to be served, noise and air pollution control procedures to be utilized, the financial and institutional framework for operation, date and time phasing of implementation, etc.

R&D policy analysis studies of the STAR type therefore precede implementation studies to help define the boundaries of feasibility and interest. Figure 1 depicts the phasing sequence for the development of public projects. Studies on the left side of the figure are oriented toward R&D policy analysis and are generally exploratory in nature, considering many diverse alternatives and emphasizing comparative analyses. In STAR analyses, for example, estimates of the absolute values of impacts are less important than relative comparisons among alternative systems.

R&D studies define the boundaries of impacts for a given set of technologies and innovative concepts. They provide guidance for decisions on the direction of future technological development and the identification of feasible concepts for further consideration.

Studies on the right side of Fig. 1 are of the implementation

Comparative analysis ←——————→ Hard number analysis

Public and interest ←——————→ Legislative, contracting
group interaction   and management

Number of
alternatives treated
(illustrative)——→   10   5   2   1   1

| Desirability analysis | Interaction and iteration | Feasibility analysis | Interaction and iteration | Political decision process | Implementation planning | Implementation | Operations |

•Costs and major   —Planners   •Costs and all   —Public   •Select "best"   •Specifications   •Contracting   •Service
 impacts (benefits   decision relevant   alternatives   •Budget projections •Construction   •Impacts
 and disbenefits)   —Technical   impacts quantita-   —Professional   •Legislation   •Fund raising   •Maintenance
 analyzed quanti-   review   tively evaluated   preparation   •Legislating   •Financial
 tatively   committee   •Interact with public —Interest groups   •Establish finance
                                                                                                           arrangements
•Define and gather
 additional
 required data for
 feasibility phase

Time ——————→

Fig. 1--A phasing program for public projects

variety. Their purpose is to develop specific system designs and plans
for implementation. They are not primarily exploratory; rather they
emphasize obtaining best estimates of system design for a specific set
of pre-defined circumstances.

Considering the sequence in Fig. 1, the STAR methods, techniques,
and computer programs are most applicable to studies included in the
left half of the chart. The methods developed take full advantage of
the comparative nature of the analysis. In addition, the scorecard
presentation of impacts in terms of their natural physical units de-
scribed below is a powerful presentation tool that readily lends it-
self to public interaction and discussion. This, of course, is a very
important requirement for this type of analysis.

The following sections discuss the features of the STAR analysis
procedure.

FEATURES OF SYSTEMS IMPACT ASSESSMENT

Historically, transportation systems have often been evaluated
primarily in terms of their costs and travel time savings. However,
as discussed in Sec. I, a more general approach in which a wide range
of impacts are considered is now more appropriate. Thus, we must con-
sider various effects on the environment and other segments of society--
what economists sometimes refer to as "externalities." In addition, we
must consider not just the aggregate impacts for a region, but also the
distributional impacts--how the various benefits and disbenefits are
distributed among different social groups (e.g., income or race).

From an analytic point of view, however, one price we pay for
greater comprehensiveness is to increase the dimensionality of the de-
cisionmaking problem. Systems must now be evaluated in terms of many
different and diverse attributes. In addition, the planning process
is greatly expanded to include decisionmakers at multiple levels of
government (e.g., federal, state, and local) and members of affected
communities. The existence of multiple impacts and the diversity of
decisionmakers greatly compounds the problem of trying to develop prac-
tical measures of effectiveness for comparing systems. One approach
might be to somehow weight individual impacts by their relative worth

(or importance) and then combine these into one single commensurate unit such as dollars, worth, or utility. Aside from the practical problem of developing such weights, this approach would have several disadvantages.

First, a single measure might help us choose between systems but it would not tell us what was required to improve a system because it would not identify areas of strength or weakness. Thus, a system that had financial problems but only mild environmental impacts would dictate different R&D policy decisions than one with just the opposite situation. Also, a single measure of effectiveness would not allow for analyses of the comparative advantages and disadvantages across impacts between systems.

Thus, the "importance" of differences between systems would be difficult to evaluate. Another disadvantage is that impacts that could not be quantified would have to be omitted from the analysis or would have to be presented in a form that was not commensurate with the rest of the analysis. For example, such impacts might be the destruction of historical monuments and recreation areas, or adverse ecological impacts.

Finally, any single measure of effectiveness or worth depends upon the relative weights given to different impacts when they are combined and upon the assumptions used to equate them with commensurate units. Unfortunately, in some cases, when the analysis is complex, these weights and assumptions are often not made completely explicit to the decisionmaker, leaving him vulnerable to the effect of hidden judgments of the analyst. Yet, these judgments may be based upon speculative or fragmentary data or upon different personal values than those held by the decisionmaker. The problem is greatly compounded, as we previously mentioned, when dealing with a diversity of decisionmakers in multiple levels of government and within the community. In such situations, as indicated by Fig. 1, development of agreement on the desired weighting or importance of various impacts is a significant part of the decision process itself, and comes from mutual interaction between concerned decision groups. Such agreement becomes a necessary prerequisite for eventual implementation of new systems.

Because of these problems, the STAR methodology was developed within the framework of the *System Impact Assessment* approach to systems evaluation, presenting impacts (described below) in terms of their natural, physical units, rather than converting them to some other scale such as dollars or an abstract measure of "worth." Also, some impacts are represented by words, where appropriate. For example, for the destruction of a historical landmark, its name would be identified and damage described rather than attempting to estimate the costs to national culture.

To facilitate comparisons for the many impacts required, Rand developed a presentation technique called the *colored scorecard*, which provides the decisionmaker with an effective picture of the relative advantages and disadvantages of alternative systems he is comparing. The technique presents a column of impacts (with each impact in its own natural units) for each alternative system being compared. Then, colors are added to indicate each system's ranking for a particular impact: green shows the best value, blue the next best value, orange an inferior value, and red the worst value. These colors are meant to show only the system rankings for a particular impact, not estimates of performance; this is shown by the impact values themselves which are visible through the colors. Figure 2 shows a sample scorecard.

The scorecard allows the decisionmaker to give each impact whatever relative weight he deems appropriate. It helps him to see quickly and easily the relative strength and weakness of various systems, to consider impacts that cannot be expressed in quantifiable terms and to change his subjective weightings and note the effect this would have on his choice of systems. It also is a useful tool for interaction with the public. This presentation technique has been favorably received by a variety of decisionmakers, ranging from federal transportation and environmental policymakers to state legislators and local planners.

Table 1 summarizes the general features of the STAR impact assessment methodology described implicitly and explicitly above. The remainder of this section discusses the various components of the STAR analysis procedure.

	Base (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Annual pax volume (millions)	6.5	5.4	5.3	4.9	9.1	5.8
Annual pax miles (millions)	1956	1660	1709	1463	2440	1625
Cost/pax mile (cents)	4.34	6.34	5.79	6.00	15.41	8.20
Capital investment required (millions)	135	145	305	190	1856	434
Annual subsidy required (millions)	0	0	0	0	277	74
Door-to-door time: LA-SF (minutes)	171	157	145	145	199	314
Door-to-door cost: LA-SF ($)	17.17	23.71	21.66	21.69	18.46	18.49
Employment-net change in peak year (000's)	0	1	14	5	52	11
Urban land acquired (acres)	0	0	135	12	514	4
Household noise impacts (No. of Households)	64029	193267	31521	21523	4989	8463
Nonbusiness uses (% of users)	56.9	51.3	54.2	54.6	62.8	68.5
Non-white noise exposure (% of all exposed)	8.8	9.7	11.9	7.8	5.7	9.9
Low-income users (% of users)	13.0	13.0	12.9	12.9	13.0	24.3

Best	Green
Next Best	Blue
Inferior	Orange
Worst	Red

Fig. 2--Summary scorecard: reference cases (sample only)

Table 1

THE STAR APPROACH: SYSTEM IMPACT ASSESSMENT

o   Considers *wide* range of impacts--includes "exter-
    nalities"

o   Considers *distribution* of costs and benefits
    (among different social groups)

o   Uses *colored scorecard* to display complex impacts
    (does not use single effectiveness measure)

o   *Compares alternatives* but leaves value judgments
    to decisionmakers

o   Makes extensive use of quantitative methods and
    computer models

o   Allows inclusion of nonquantifiable impacts

o   System alternatives may be
    - Technological (e.g., add trains)
    - Institutional (e.g., financial subsidy)
    - Combination

o   Method applicable to many policy problems having
    complex effects

STAGES OF ANALYSIS

Figure 3 illustrates the stages of the STAR analysis. In this
approach, the planner defines and describes one or more alternative
transportation systems he wishes to evaluate and describes the region
in which these systems are to operate and for which the selected set
of impacts will be analyzed. A particular mix of transportation tech-
nology modes (e.g., auto access and vertical takeoff and landing air-
craft (VTOL)) viewed in the context of a particular regional forecast
define a specific *case* for analysis (e.g., 1985 conventional takeoff
and landing aircraft (CTOL) and auto access evaluated in the California
Corridor with competing auto and bus modes, assuming 1970 population).
The cases and the related set of impacts form the basis for the STAR
analysis. Results are then evaluated and prepared in the colored
scorecard format.
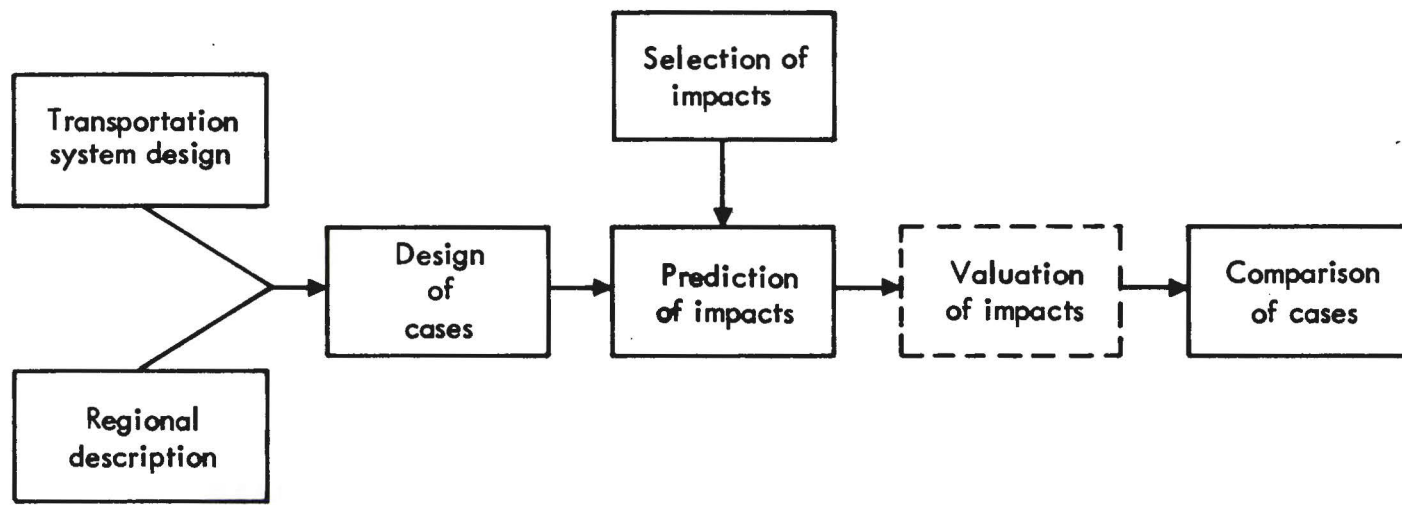
Fig. 3--Stages of analysis

IMPACT SELECTION

STAR impacts fall into five general categories: service, financial, economic, community, and social.

Service impacts are those that system users (i.e., the travelers) perceive. Financial impacts pertain to the system operator who will build and operate the system and who must know the potential for adequate returns on investments and the costs of operating the system. Economic impacts deal with the economic effects on the region of building the system. Community impacts deal with disturbances to existing activity patterns within local communities, potential fiscal problems created for local governments, and changes in the physical environment as a result of constructing or operating the new system. Examples of such impacts are land acquired, households displaced, taxes lost, energy requirements, air pollution, and households impacted by excessive noise. Social impacts indicate the distribution of benefits and disbenefits among major socioeconomic groups (e.g., business and non-business use, and low income users).

Service and Financial Impacts

The STAR analysis used the following basic set of service and financial impacts:

o   Annual passenger volume (number of passengers/year)
o   Annual passenger miles
o   Cost/passenger mile
o   Capital investment required
o   Annual subsidy required (if any)
o   Door-to-door time: for selected origin-destination pairs
o   Door-to-door cost: for selected origin-destination pairs
o   Potential effect on congestion--as measured by number of passengers diverted from existing facilities

In addition to this basic set presented in the scorecard, the methodology also produces more detailed data. Thus, for example, the supply-demand model, discussed later, produces for each origin-destination

pair used in the analysis the following data: demand, frequency of service, door-to-door travel time, and door-to-door cost. In addition, these data are produced for business and nonbusiness travel. (For these items alone STAR runs produce 16,000-20,000 data values.) The program also produces detailed investment and operating cost break-downs that are available for more detailed analysis should they be required.

R-1359/4-DOT describes the printout produced by the supply-demand program. These additional items in the printout are available for inclusion in the scorecard should study requirements warrant it.

Economic Impacts

New intercity transport systems potentially involve large outlays for manufacturing equipment and constructing terminals and guideways. These expenditures spread over some period will create employment and generate income within the study region and elsewhere. These effects may or may not be significant in any given situation.

The present methodology provides time-phased estimates of sales, employment, and payroll attributable to construction expenditures within the region. It also can be used to indicate potential "bottlenecks" that might occur in various industrial sectors of the region should existing manufacturing capacities be exceeded.

The scorecard uses the following specific economic impacts for the peak-year impact of construction:

o   Sales (dollars)
o   Employment (number of people)
o   Payroll (dollars)

In our experience, the potential impact of expenditures for maintenance and operations once a system is established are insignificant relative to the effect of large expenditures required for construction and implementation. Hence the STAR methodology emphasizes evaluation of construction impacts. A similar procedure could be used for operating expenditures if they were significant.

Community Impacts

The following basic set of community impacts are used:

o Urban land acquired (acres)

o Rural land acquired (acres)

o Taxes lost (dollars)[5]

o Households displaced (number of households)

o Energy used for operation (BTU/day)

o Air pollution (daily emission levels)

o Household noise impacts (number of households receiving excessive noise)

R-1359/5-DOT describes the procedures used to estimate these impacts.

Social Impacts

Social impacts concern the incidence or distribution of benefits and disbenefits that new systems provide among major social groups within the study region.

People who would be affected by the installation and operation of new short-haul systems can be classified in many possible ways. STAR classifications were primarily dictated by available data resources. Travelers, the people who benefit from new systems, can be classified by trip purpose and by income. People who live near the guideways, runways and terminals, who are unfavorably affected by the installation of or operation of these systems, can be classified by income and ethnic background. Figure 4 illustrates these classifications.

Our primary source of demographic data for estimating these impacts was the First Count Summary Tape of the 1970 Census of Population and Housing. At the time of our study, these were the only data available.

---

[5]This refers to taxes lost as a result of the removal of land or improvements for use of a proposed transportation system. Other items such as revenues from business at terminal facilities or the attraction of tax paying business concerns, are not considered in the current analysis. In situations where these items are significant, they should be included in the impact estimate.

$$
\text{Travelers} \quad
\begin{cases}
\text{Trip Purpose} & \begin{cases} \text{Business} \\ \text{Nonbusiness} \end{cases} \\[2em]
\text{Income in 1970} & \begin{cases} \text{Low (under \$6,000)} \\ \text{Middle (\$6,000-\$14,999)} \\ \text{Upper (15,000 or more)} \end{cases}
\end{cases}
$$

$$
\text{Residents} \quad
\begin{cases}
\ \\[3em]
\text{Ethnic Background} & \begin{cases} \text{White (includes Mexican-Americans)} \\ \text{Black} \\ \text{Other} \end{cases}
\end{cases}
$$
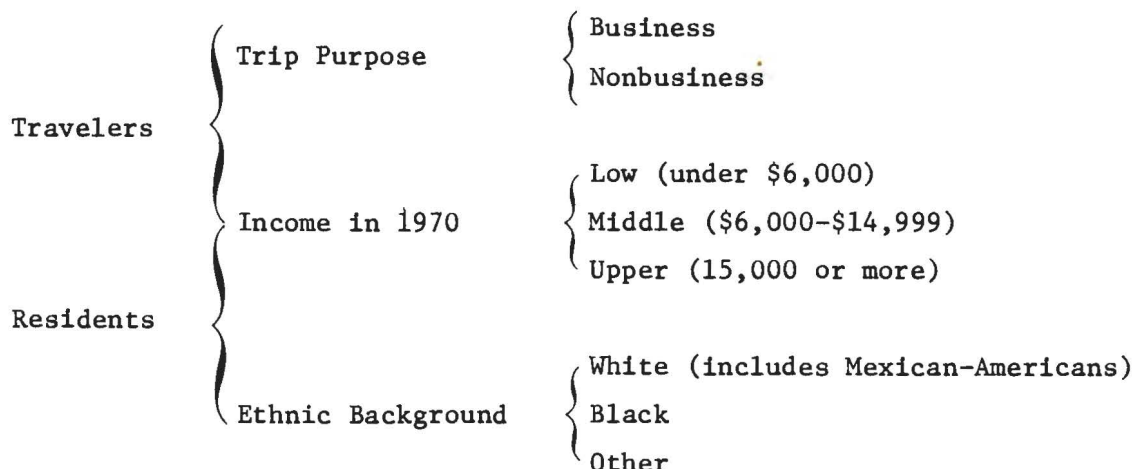
Fig. 4--Definition of incidence groups

In addition, the tape provided data at the Block Group[6] level that are essential for the analysis.

The First Count Summary Tape was adequate in most respects; however, it did not include data on income or planar coordinates. The required coordinate data were obtained from a Medlist[7] tape prepared by the Census Bureau. Income data, however, had to be estimated as a function of housing market value or contract rent. R-1359/1-DOT describes procedures used for making these estimates. With respect to ethnic background, Mexican-Americans are included along with whites and cannot be distinguished.

Estimates on the distribution of travelers by income were based upon data presented in the 1967 Census of Transportation, National Travel Survey, published by the Bureau of Census. R-1359/4-DOT discusses procedures used in making these estimates.

The present methodology provides estimates on the division of

---

[6] File A of the First Count Summary Tape was the one utilized in the analysis. This file reports data separately for each Block Group (BG) in urban areas and Enumeration District (ED) in rural areas. There are about 25,000 such units of area in California, each designed to contain the homes of about 1,000 people.

[7] Master Enumeration District List containing a hierarchical code list relating each state, county, minor civil division, and place segment by name to all relevant census geographic codes.

travel between business and nonbusiness purposes for each mode. It also estimates the distribution of travelers by income group and trip distance. For residents, estimates of the numbers of noise-impacted households by income and ethnic groups are provided. In the STAR analysis, the following summary incidence measures were used in the scorecard:

o   Nonbusiness users (percent of all users)

o   Low-income users (percent of all users)

o   Low-income noise exposure (percent of all exposed)

o   Nonwhite noise exposure (percent of all exposed)

TRANSPORTATION SYSTEM DESIGN

The planner will specify each transportation system he wishes to analyze. Each system will consist of a mix of short-haul and access modes. *Short-haul modes* are air systems, ground systems, or both for which R&D decisions must be evaluated. *Access* modes are defined based upon available modes of transportation in the communities serviced by short-haul terminals (e.g., private auto, taxi and public transit).[8]

The analysis requires descriptions of a variety of transportation system parameters. Some of this information is obtained directly from the design engineers developing the specified systems. This is true for many performance and cost parameters. However, much of the required information depends for definition upon the region of implementation and, thus, must be prepared as part of the analysis. In this category are airport description, network specification, access analysis, and many service and cost parameters. An example of the types of descriptive analyses performed for each mode is presented below:

Air Mode

o   Airport site selection and evaluation

---

[8] Access times and costs can also be varied parametrically to study possible benefits that could be derived by improving access systems.

o   Detailed airport description for use in community impact
    assessment

o   Airport operational constraint analysis

Ground Mode

o   Guideway route selection and analysis

o   Estimation of terminal and network costs

o   Operation and performance analysis

o   Land requirements analysis

o   Detailed route description for use in community and social
    impact assessment

Access

o   Prepare estimates of average access and egress times and
    costs for each short-haul terminal.

R-1359/3-DOT and R-1359/6-DOT describe procedures for performing
these analyses. R-1359/3-DOT describes requirements for evaluating
service and financial impacts; R-1359/6-DOT describes requirements for
evaluating community impacts.

The methodology also allows specification of highway modes--pri-
vate automobile and bus--that compete with the short-haul modes for
passengers. For the automobile mode, travel times and distances are
estimated based upon the existing highway system and assumptions about
new links that might be added during the analysis period. Travel costs
are based upon a cost/mile parameter that the analyst specifies. This
can either reflect existing costs or be varied to evaluate the effects
of potential changes in costs.

The bus system is specified in terms of travel times, travel costs,
and frequencies of service. These estimates include assumptions on
terminal access times and costs. The analyst prepares estimates as
part of the system design task. These estimates can reflect either
existing or proposed new systems.

REGIONAL DESCRIPTION

The planner specifies a region within which his innovative short-
haul systems are to be evaluated. In general, this will comprise a

relatively cohesive and self-contained short-haul travel market such
as the California and Northeast Corridor areas. Once the study region
is defined, demographic, economic, travel, geographic, and physical
data on the region have to be prepared. Also, future values for these
items may have to be obtained when regional forecasts are utilized.
In addition, zones of travel (superdistricts) within the region must
be defined.

Demographic Data

Detailed demographic data at the Block Group level are required
to evaluate community and social impacts. As mentioned above, the
source for these data is the Census First Count Summary Tapes for the
region of interest. These tapes are adequate in most respects, but
require the addition of geographic coordinates for Block Group centroids
and income data for Block Group residents. Block Group coordinates can
be obtained from Medlist tapes prepared by the Census Bureau. In-
come data must either be estimated based upon housing market values
and contract rent or by extrapolation from Fourth Count Census income
data aggregated at the Census Tract level.[9]

R-1359/1-DOT describes procedures for preparing demographic and
income data required for the analysis.

Travel Data

Detailed intercity travel data for trips longer than 50 miles and
shorter than 500 miles are required to estimate parameters (calibrate)
in the demand estimation equations used in the analysis. These equa-
tions are described in Sec. III. For each superdistrict pair, data
must be obtained on the number of daily trips, frequency of service,
travel times, and travel costs. These data must be further categorized
by trip purpose, i.e., business and nonbusiness. The data must be
gathered for all prevailing travel modes, including automobile, bus,
air, and rail when service is available. In addition, for each

---

[9] Census tracts generally contain 4-9 Block Groups. However, in-
come data are not provided at the Block Group level, the unit of ag-
gregation required in the analysis.

short-haul terminal, access times and costs must be estimated for the
area serviced by the terminal.

The sources of travel data will generally be transportation plan-
ning agencies within the region. For the STAR analysis, the California
State Division of Highways provided required automobile data; origin-
destination data on intrastate air carriers were provided by the Cali-
fornia State Public Utilities Commission. This agency also provided
the available data on bus travel. The Federal Civil Aeronautics Board
provided travel data for interstate air carriers. Air travel service
characteristics were obtained from schedules published in the Official
Airline Guide.

In most cases, travel data that the analyst obtains will come
from several sources where they were collected at different points in
time and for various purposes. The analyst will therefore have to
build a composite data picture, retaining data thought to be valid and
rejecting items thought to be inappropriate. In some cases, missing
data will have to be extrapolated from similar items thought to be
valid. Also, large numbers of data elements are involved in this pro-
cess (e.g., approximately 10,000 data items of this type were required
for STAR analyses in the California Corridor), making it more complex.

R-1359/2-DOT presents procedures for performing this task as well
as those for collecting, evaluating, and using required travel data
for calibrating the demand equations.

Physical and Geographical Data

As indicated above, considerable data describing the geographical
and physical characteristics of the region must be prepared to evaluate
competing systems. Air modes require data describing existing airport
facilities and air operations, and land use data must be prepared to
evaluate the effects of new facility construction. For ground modes,
data on existing or proposed rights-of-way must be collected, including
surrounding land use characteristics; topographical properties, includ-
ing grade and curvature; existing or proposed grade crossings, includ-
ing estimates of the amount of cross traffic to be expected; and geo-
logical properties that might affect construction costs. Also, where

existing guideway is utilized, estimates of existing or anticipated traffic on the guideway must be obtained.

For automobile and bus, the existing intercity highway system must be described, including any new links that would be operational in the analysis period.

R-1359/3-DOT and R-1359/6-DOT present data requirements, along with procedures for performing the required system design analyses. R-1359/3-DOT describes requirements for evaluating service and financial impacts; R-1359/6-DOT describes requirements for evaluating community impacts.

Economic Data

R-1359/5-DOT describes the data requirements and procedures for evaluating the economic impacts of system construction. As indicated in that volume, all of the required regional data can usually be obtained from readily available resources. For a specified region, this will consist of a regional input-output model, along with other standard sales and employment data.

Regional Forecasts

Regional forecasts (i.e., projections of future demographic, economic, geographic, or travel characteristics for the region), when used in the analysis, constitute part of the regional description data. Generally, such forecasts will be obtained from planning agencies within the region. Forecasts might be made for any or all of the above region description items. The STAR approach to case analysis utilizes such forecasts in the context of evaluating relative sensitivities of estimated impacts to changes in regional characteristics. Such prospective changes to the region are introduced to the analysis on a "component" basis in the form of excursion cases. Comparisons are then made of results for each system for these excursions. Interesting sensitivities pertinent to R&D decisions can then be evaluated. This general procedure is discussed later.

Superdistrict Definition

The study region is divided into basic short-haul travel zones
called superdistricts, which form the basis for defining short-haul
trips and are used for evaluating service and financial impacts.
Superdistricts are designed as much as possible to conform to exist-
ing travel patterns in the region.

In the California Corridor, as shown in Fig. 5, superdistricts
are generally designed to conform to county boundaries, except in some
cases such as Los Angeles where additional resolution between zones
with differing socioeconomic characteristics was desired, counties
were split between superdistricts.[10]

R-1359/1-DOT presents exact definitions of boundaries for each
superdistrict used in the California Corridor.

CASE DESIGN

A case consists of a mix of transportation systems (short-haul
modes plus their associated access modes) plus a regional description.
For each case defined in the study, impacts are predicted and score-
cards depicting these impacts are prepared. A typical case for analy-
sis might consist of an advanced technology air mode, and/or an ad-
vanced technology ground mode, with competing auto and bus modes
operating in a specified region for a specified point in time. Data
for each of these items are prepared as part of the system design
and region description tasks discussed above.

In the STAR impact assessment approach, *reference cases* are first
evaluated in which the specified future transportation systems are
analyzed in the context of *today's world* (present population, travel
characteristics, land use, etc.). This provides insight into relative
advantages among systems without requiring uncertain forecasts of pos-
sible future worlds. The analyst thus first understands how these
systems would perform if they were operational today. Later, using

---

[10]The California Corridor was divided into 26 superdistricts. The
maximum possible with the current methodology is 29. This could be
changed, but would require modifications to the supply-demand program,
a major computer program used in the analysis.
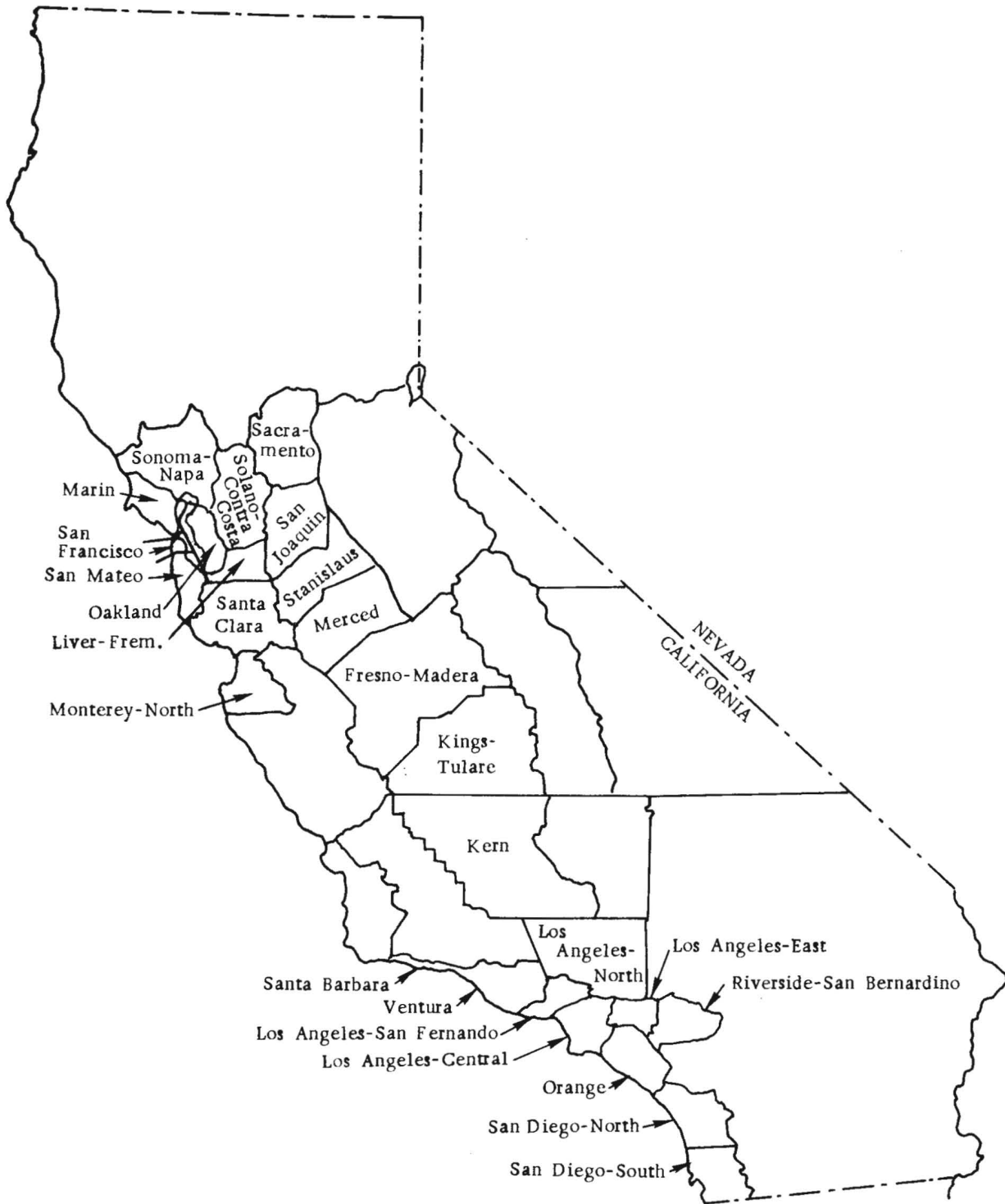
Fig. 5--STAR superdistricts

excursion cases (i.e., cases in which either the transportation systems or regional descriptions used in reference cases are modified), he will evaluate the effect of possible future regional development.

After the reference cases have been evaluated, excursion cases are analyzed to evaluate the effect of possible system or regional changes. The reference cases evaluate normative[11] designs (or what might be considered the most representative future designs) for the specified transportation systems. Excursion cases can then be used to evaluate variations of these designs along with the effects of alternative regional forecasts.

In general, there will be too many cases if an attempt is made to consider all possible combinations of system and regional variations. Rather, the analysis should be limited to decision-relevant excursions-- only ones that might affect comparisons among alternative systems. Thus, the analyst should design excursions to investigate upper and lower bounds, should resolve uncertainty in the favor of lower ranking systems,[12] and, for some cases, should determine how assumptions must change before rankings change (and then the analyst should ask whether such changes are plausible).

Case design, therefore, is an iterative process. First, a set of reference cases is defined, including the most representative versions of the systems to be evaluated. The systems are then analyzed in the context of the present world.

The reference cases also include the *base case,* which represents the most probable system to be operating in the specified period if existing trends and plans continue. In STAR, the base case included, besides automobile and bus, an advanced CTOL aircraft operating out of existing airports in the region. Compared with aircraft flying today,

---

[11]STAR I referred to these as nominal cases.

[12]If a system is doing poorly in the comparisons and there is un-certainty about the proper set of assumptions to make, evaluate it under optimistic circumstances. Then, if it still does poorly, it can be eliminated from further consideration. If it improves its relative ranking, further analysis can be performed to resolve its proper role.

the advanced CTOL is bigger, more economical to operate because of
size, and quieter because of substantial noise abatement. The base
case is the system against which alternative systems must be compared,
for it reflects what will probably happen if no changes take place in
current plans.

A full set of impacts is predicted for all reference cases, in-
cluding the base case, and comparisons are made using scorecards.

At this point, sensitivity analyses can be performed on individual
systems for impact areas that appear important in the comparison. For
specific systems, changes in design can be tested and their effect on
troublesome impacts observed. If a comparison-relevant change occurs
in the specified impact, the new system can be evaluated for the full
set of impacts and added to the scorecard.

After this analysis, a set of excursion cases can be run in which
regional changes are hypothesized. Here, as before, the important
things are decision-relevant changes. Will future population increases
cause changes in the relative comparisons between systems? If so, at
what levels will this occur? Are these changes plausible when compared
with available forecasts for the region? What changes in population
distribution and land use within the region might affect this compari-
son? Are these changes plausible in the analysis period? What are
the effects of possible future changes in travel behavior (relative
weight given to travel time, travel cost, and frequency of service by
passengers making their decisions to travel and choice of mode)? Are
such changes plausible? Scorecards presenting impact estimates are
again prepared for cases in which important changes in the comparisons
occur. At this point, another round of system sensitivity analysis
for selected impacts can be performed.

Finally, a set of summary scorecards is prepared containing com-
parisons for both the reference cases and those excursion cases in
which significant changes in rankings occurred.

ESTIMATION OF IMPACTS

Analytic procedures for estimating impacts are depicted schemat-
ically in Fig. 6. For each case description, parameters are prepared
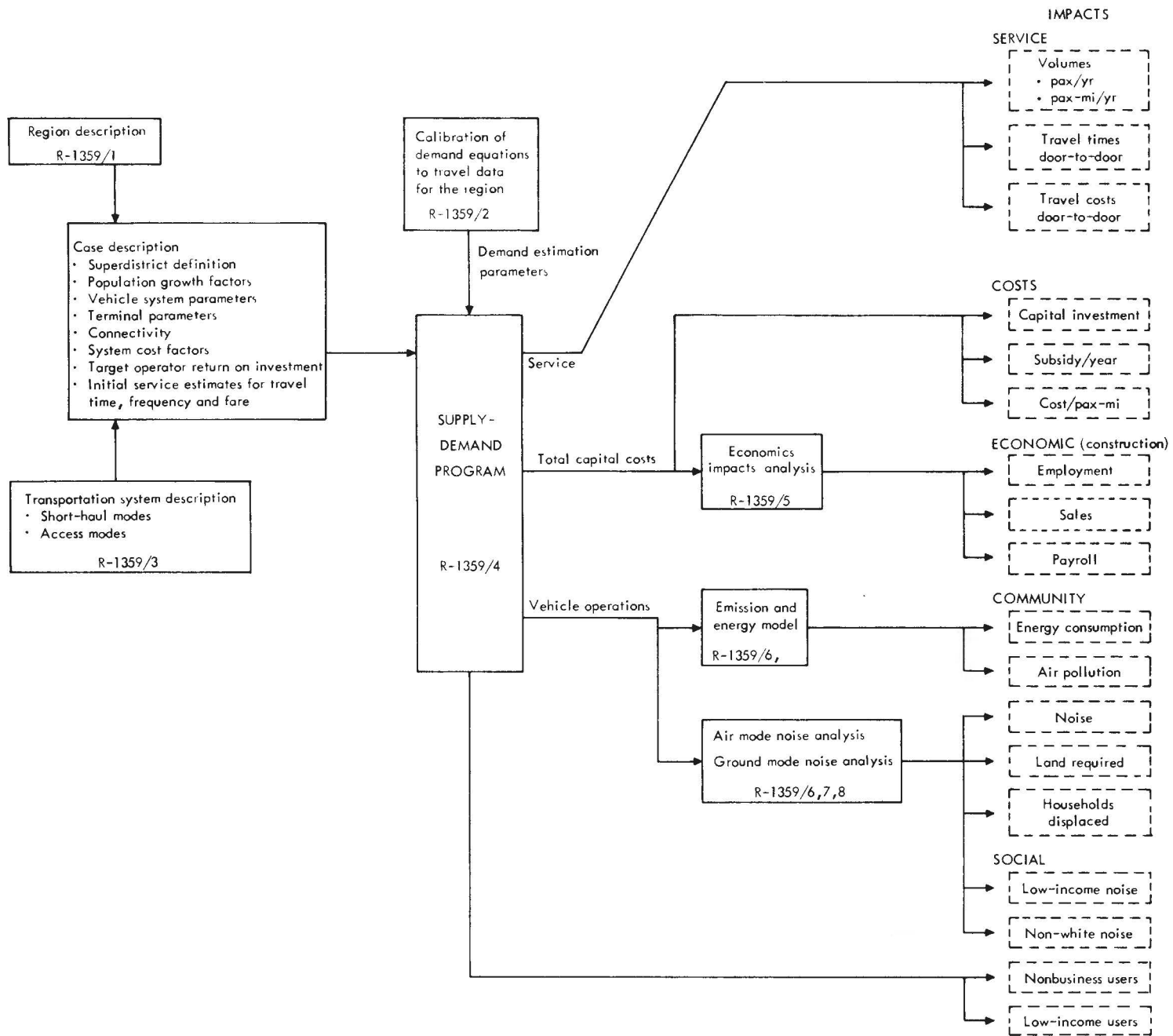
Fig. 6--STAR analysis procedure

using data developed in the region and transportation system descriptions. Case descriptions are then used as input to the supply-demand program and the other STAR analysis programs. The supply-demand program directly calculates service and financial impacts and supplies other data required for evaluating economic, community, and social impacts.

After appropriate preparation of inputs, the program can evaluate a single air mode along with a competing auto mode and bus mode; a single ground mode along with a competing auto mode and bus mode; and a single air mode competing with a single ground mode along with a competing auto mode and bus mode.

The program assumes that the operator of an air or ground mode uses a single vehicle type to meet available demand. When vehicle mixes must be evaluated, the analyst can (1) specify average vehicle characteristics, depending upon the fleet mix; and (2) evaluate each vehicle of the fleet in differing subregions (i.e., one or more super-districts but less than the entire study region) of the study area. For example, the analyst can match appropriate vehicles for high- and low-density areas. Using both approaches, he then can determine the desirable mix.

Other major parts of the methodology include the air and ground mode noise analysis programs, the economic analysis procedures, the emission and energy program, and procedures for calibrating the demand equations used to estimate travel demand in the analysis.

IMPACT VALUATION

After impacts have been estimated in terms of their natural units, the analyst may decide to also expand a particular impact in terms of some desired unit to provide additional insight. For example, he may estimate the costs to reduce pollution emissions from predicted levels. This task will differ in each situation, depending upon particular study requirements. For this reason, it is represented by a dotted line box in Fig. 3. In STAR analyses, the impacts described in the previous paragraphs on impact selection were adequate for making the required system comparison.

CASE COMPARISON

The basic strategy for comparing systems was discussed earlier when case design was described. Case comparison involves selecting and presenting impacts. Then the analyst reviews the results to determine whether they are presented in a form most meaningful for the comparisons in view of the policy issues of interest to the decision-maker. He might decide to further aggregate some impacts or disaggregate others. He might decide to add to the scorecard additional data produced in the analysis.

In the analysis, first the reference cases are evaluated and compared with the base case. Figures 7 to 10 present sample scorecards for each impact category. A summary scorecard, as illustrated in Fig. 2, is then prepared showing all impact categories. Excursion cases are then evaluated and similar scorecards can be made and changes in system ranking between excursion and reference cases noted.

	Base (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Annual pax volume (millions)	6.5	5.4	5.3	4.9	9.1	5.8
Annual pax miles (millions)	1,956	1.660	1,709	1,463	2,440	1,625
Cost/pax mile (Cents)	4.34	6.34	5.79	6.00	15.41	8.20
Capital investment required (millions)	135	145	305	190	1,856	434
Subsidy/year (millions)	0	0	0	0	277	74
Door-to-door time: L.A.-S.F. (min)	171	157	145	145	199	314
Fare: L.A.-S.F. ($)	13.84	20.22	19.19	19.51	15.00	15.00
Door-to-door costs: L.A.-S.F.($)(business)	17.17	23.71	21.66	21.69	18.46	18.49
Door-to-door cost: L.A.-S.F.($)(non-business)	15.42	21.92	20.24	20.56	16.70	16.73

Best	Green
Next Best	Blue
Inferior	Orange
Worst	Red

Fig. 7--Scorecard: reference cases (sample), service and costs

Peak-Year Impact of STAR Construction	Base (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Total Sales ($M)	0	14	287	92	1074	274
Total Employment (1000)	0	1	14	5	52	11
Total Payroll ($M)	0	5	120	38	449	113

Best	Green
Next Best	Blue
Inferior	Orange
Worst	Red

Fig. 8--Scorecard: reference cases (sample), economic impacts

	BASE (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Urban land acquired (acres)	0	0	135	12	514	4
Rural land acquired (acres)	0	0	0	0	8304	0
Taxes lost ($ millions)	0	0	0.2	0.1	2.0	0
Households displaced	0	0	0	0	248	5
Energy (bill, BTU/day)	17	32	21	26	21	6
Air pollution	✓	✓	HC	HC	✓	✓
Household noise impacts	64029	193267	31521	21523	4989	8463

Best	Green
Next Best	Blue
Inferior	Orange
Worst	Red
✓ =	Comparable but insignificant

Fig. 9--Scorecard: reference cases (sample), community impacts

	Base (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Nonbusiness users (% of all users)	56.9	51.3	54.2	54.6	62.8	68.5
Low-income users (% of all users)	13.0	13.0	13.0	13.0	13.0	24.3
Low-income noise exposure (% of all exposed)	12.2	13.8	16.3	12.8	8.8	14.3
Non-white noise exposure (% of all exposed)	8.8	9.7	11.9	7.8	5.7	9.9

Best	Green
Next Best	Blue
Inferior	Orange
Worst	Red

Fig. 10--Scorecard: reference cases (sample), social impacts

III. OVERVIEW OF STAR METHODOLOGY VOLUMES

This section briefly discusses the contents and use of each aux-
iliary volume to this report. In performing an analysis, the present
volume should be read first to obtain an overview of the basic concepts
and procedures. Then each specific part of the analysis can be per-
formed using Fig. 6 as a guide, and referring to the appropriate
STAR volume for detailed procedure and computer program descriptions.
Throughout these volumes, a representative selection of air and ground
mode short-haul systems designed for use in the STAR analysis of the
California Corridor are used to illustrate the methodology.

STAR Methodology Series

REGIONAL DESCRIPTION: R-1359/1-DOT

This volume should be used to perform regional description tasks
associated with defining superdistricts and preparing demographic data.
It discusses the selection and description of the superdistricts--often
equivalent to counties--as the demographic areas into which the Cali-
fornia Corridor was divided for analysis. Since the First Count Census
did not contain the household income data necessary for the analysis,
the information was estimated from the contract rent and property value
data given on the census tapes; this estimation procedure is described.
Population estimates for 1985 are provided for use in the excursion
cases. Then the several procedures necessary to add geographic coor-
dinates to the census data and otherwise prepare the STAR census data
tapes for use in the noise analysis are described, as well as the pro-
cedure for mapping census data.

DEMAND PREDICTION--APPROACH AND CALIBRATION: R-1359/2-DOT

This volume describes the demand model used to estimate travel de-
mand and modal split and procedures for calibrating the model to travel
data in the study region. Also described are data used in the STAR
analysis for calibration to the California Corridor.

The demand model is imbedded within the supply-demand program that estimates travel volume and service characteristics for all modes in the analysis. The supply-demand program was developed for the Northeast Corridor study[1] by MITRE and was modified in part by Rand for the STAR study. The model is documented in detail by MITRE[2-6] and Rand modifications to it are described in R-1359/4-DOT. The supply-demand model estimates demand (the number who want to travel) and supply (the number the system operator will carry and characteristics of service). Then, through repeated supply-demand iterations, the model estimates travel volume and service characteristics for all the modes.

When we applied the MITRE supply-demand model, as calibrated to the Northeast Corridor, to the California region and compared predicted results with actual travel data, there were large differences in total demand and modal split (travel demand for each transportation mode in the region). We concluded that even if we recalibrated the MITRE-NEC model, its predictions would be inadequate for the STAR analysis. Accordingly, we developed a new approach to predicting total demand which includes link-specific calibration factors (i.e., factors relating to characteristics of the trip origin and destination points). We also modified the form of the modal split equations, going from the MITRE implicit mode form (requiring specification of subjective attractiveness factors for each mode) to a pure abstract mode form, where modal choices are made on the basis of relative time, cost, and frequency of service. In summary, we

(1) developed a new approach for predicting total demand;

(2) modified the existing method for predicting modal split; and

(3) calibrated these to California travel data.

Approach to Demand Prediction

The MITRE-NEC formulation for predicting demand for travel between superdistricts i and j is

$$D_{ij} = e^{\beta_1} \left[F_i F_j\right]^{\beta_2} \left[W_{ij}\right]^{\beta_3} , \qquad (1)$$

where D_{ij} = demand for travel between superdistricts i and j,

F_i, F_j = the population of superdistricts i and j, as measured by the number of households (families) in the top 14 percent income group,

β_1, β_2, β_3 = constants,

W_{ij} = overall conductance (ease of travel) between superdistricts i and j, as measured by functions of service characteristics aggregated over all modes between these superdistricts.[13]

In attempting to explain why even a recalibration of this type of model would be off by large factors, we made several observations. First, the model predicts demand from scratch. And second, it ignores link-specific factors influencing demand except for population-income, frequency, travel time, and cost of service. These imply that if we apply the model to today's transportation system, predicted travel would differ substantially from the actual situation.

The above observations suggested the need for a model that (1) predicts *changes* in demand from some observed reference value instead of from scratch, and (2) incorporates link-specific calibration factors that serve as proxies for the otherwise unincluded factors affecting demand. This can be accomplished by introducing estimates of today's demand on each link into the equation and then predicting changes in this demand resulting from changes in link population and service characteristics.

The Rand formulation for demand D_{ij} between superdistricts i and j stated in words is as follows:

Future D_{ij} = (Existing D_{ij})(Change Soc. Econ.)$^{\beta_2}$(Change in Ease of Travel)$^{\beta_3}$.

More precisely, this formulation is given by

$$D_{ij} = D_{ij}^* \left[\frac{F_i F_j}{F_i^* F_j^*} \right]^{\beta_2} \left[\frac{W_{ij}}{W_{ij}^*} \right]^{\beta_3} . \tag{2}$$

_____

[13] For a quantitative definition of this term see Eqs. (4) and (5).

An (*) indicates quantities observed for the calibration year. This
is the closest year to the present for which data were available (e.g.,
for STAR, the calibration year was 1968).

In terms of the original Northeast Corridor formula, this approach
amounts to replacing the single constant term with many different co-
efficients--one for each superdistrict pair--reflecting the observed
travel between those superdistricts today. Incorporating the demand
on each link means we are no longer predicting demand from scratch.
Moreover, the link-specific demand reflects the observed propensity of
people to travel on a given link and, hence, is a good proxy for the
link-specific factors influencing demand but not otherwise included.
This empirical approach, while limited in explanatory power, was satis-
factory for STAR use and most importantly removed significant prediction
errors that would have been detrimental to the analysis. It is recom-
mended that future studies be undertaken to develop more explanatory
models that might provide insight on the basic behavioristic structure
underlying these link-specific effects.

In summary, a model of *changes* in demand implicitly captures link-
specific influences that are lost in a model predicting demand levels
from scratch. For instance, suppose the fact that San Diego has a num-
ber of special recreation facilities is an important influence on the
Los Angeles-San Diego travel; this will not be captured very well--
perhaps not at all--by just the population-income, frequency, time, and
cost variables used in the standard models that predict demand levels
from scratch. But in a model of the *changes* in demand, this influence
is reflected in the *observed* value for today's demand that is included.

Since this model of changes uses existing demand as a reference
point, it should give very reliable predictions for situations close
to the reference year and reasonable ones otherwise.

Finally, the model is better adapted for evaluating alternative
systems in the context of some future reference scenarios of demand.
The desired reference demands can be put into the model as the appro-
priate D_{ij}^{*} and changes in the D_{ij} predicted as a function of changes
in service.

Approach to Modal Split

The MITRE-NEC demand equation as calibrated to the Northeast Corridor gave poor predictions of modal split when applied to the California region. To correct this problem, we modified the form of the modal split equation, going from the MITRE implicit mode form (requiring specification of subjective attractiveness factors on each mode) to a pure abstract mode form where modal choices are made on the basis of relative time, cost, and frequency of service. We then calibrated this modal split equation to California travel data.

The form of the modal split equation is

$$D_{ijk} = D_{ij} \frac{w_{ijk}}{\sum_m w_{ijm}} , \qquad (3)$$

where

$$w_{ijk} = e^{\alpha_0} t_{ijk}^{\alpha_1} c_{ijk}^{\alpha_2} (1 - e^{-Kf_{ijk}})^{\alpha_3} . \qquad (4)$$

D_{ijk} represents the split to mode k. W_{ijk} represents the conductance (ease of travel) between superdistricts i and j by mode k. The frequency, time, and cost of service are represented by f, t, c, respectively. And the α's represent calibration coefficients.

To calibrate the α's for California,[14] we gathered data on origin and destination travel volume. Air data were taken from the CAB 10-percent survey and from the Public Utilities Commission's records on PSA and other intrastate carriers. Greyhound Lines provided us with bus volumes. For auto travel, we processed cordon survey tapes on San Diego, Stockton, Bakersfield, Sacramento, the San Francisco Bay area, and the Los Angeles Regional Transportation Survey (LARTS) area, which

---

[14]We preserved the same coefficents for the frequency term as in the MITRE model for a number of reasons: (1) in most cases, frequencies are high enough so that the entire term has little effect on demand; (2) we wanted to concentrate on comparing the time and cost elasticities of the NEC with those for California, and were willing to assume that travelers in the two corridors feel roughly the same about frequency of service.

includes San Bernadino, Ventura, Riverside, and Orange counties, in addition to Los Angeles.

The results of reestimating the modal split portion of the demand model are compared below with the NEC coefficients.

Business

	α_0	α_1	α_2	α_3	K
Rand	-0.179	-1.761	-1.684	2.279	0.12
MITRE	(a)	-3.384	-0.483	2.279	0.12

Nonbusiness

	α_0	α_1	α_2	α_3	K
Rand	0.4461	-0.9884	-1.993	2.046	0.18
MITRE	(a)	-1.582	-1.582	2.046	0.18

[a]Different coefficients are used for each mode in accordance with the implicit mode approach to predicting modal split.

Looking at these coefficients, we can see that business and non-business travelers are much less sensitive to time in California than in the Northeast Corridor. Californians seem to worry less about time and more about cost when they travel than do travelers in the Northeast.

We used a nonlinear estimation technique.[15] The statistical tests of significance are, therefore, only approximate. Both α_1 and α_2 were significant at the 1-percent level, as was the F statistic.

The service characteristic terms W_{ij} in Eqs. (1) and (2) for total demand D_{ij} have the same form as in the NEC model, which is

$$W_{ij} = \sum_m (w_{ijm})^{\beta_4} , \qquad (5)$$

where w_{ijm} = the conductances between superdistricts i and j by mode m, as defined by Eq. (4),

β_4 = a constant, the same as that used in the NECTP model.

Using (4), we can now write the complete equation for D_{ijk} as follows:

---

[15]See R-1359/2-DOT, for details of this technique.

$$D_{ijk} = D_{ij}^{*} \; [G_i G_j]^{\beta_2} \left[\frac{\sum\limits_{m} (w_{ijm})^{\beta_4}}{\sum\limits_{m} (w_{ijm}^{*})^{\beta_4}} \right]^{\beta_3} \frac{w_{ijk}}{\sum\limits_{m} w_{ijk}} \; , \qquad (6)$$

where $G_i = (F_i)/(F_i^{*})$, $G_j = (F_j)/(F_j^{*})$ = growth factors, relative to the calibration year, of the number of households (families) in the top 14 percent income group.[16]

β_2, β_3, β_4 = the same as those used in the NECTP model.

TRANSPORTATION SYSTEM DESCRIPTION: R-1359/3-DOT

To use the supply-demand program to compare modal systems, information on a wide range of modal system parameters has to be prepared as program inputs. Some of this information is obtained directly from the design engineers developing the specified systems, i.e., for many of the vehicle specification parameters and some cost parameters. However, most inputs require extensive analysis for their preparation. In this category are airport description, ground mode network specification, access analysis, and many service and cost parameters.

This particular volume serves three purposes:

1. It describes the procedures required to develop detailed descriptions of specific transportation systems for analysis using the supply-demand model;

2. It presents procedures for converting modal system parameters into model inputs; and

3. It documents specific systems developed for STAR as demonstrations of the system description methodology.

---

[16] In the STAR analysis, it was assumed that the number of families in the top 14 percent income group grew at the same rate as the rest of the households in the region. Hence, for STAR, the G's were specified as the total household growth factors for the region. In other studies the G's will be based on available data for the study region, not necessarily the assumption described above.

For purposes of illustration, several kinds of systems were described.

o   Automobile (nonreactive)[17]

o   Bus (nonreactive)

o   CTOL (reactive, using existing terminal network)[18]

o   RTOL (reactive, using modified terminal network)

o   STOL (reactive, using some new terminals)

o   VTOL (reactive, using some new terminals)

o   IPT (reative, using mostly existing guideway and terminals)

o   TACV (reactive, using all new guideway and terminals)

Each of these systems presents a somewhat different set of parameters to be considered in preparing the model inputs. It is believed that this set of systems demonstrates most of the system description methodology that future investigators may need.

PREDICTION OF SERVICE AND FINANCIAL IMPACTS USING THE SUPPLY-DEMAND PROGRAM: R-1359/4-DOT

Service and financial impacts are predicted using the supply-demand program. The program also provides important inputs to the other parts of the analysis. The program is documented in detail by MITRE[(2-6)]. This volume discusses procedures for using those portions of the NEC model modified by Rand.

The supply-demand model estimates demand (the number who want to travel) and supply (the number the systems operator will carry and

---

[17] The terms *reactive* and *nonreactive* refer to the manner in which modes are utilized in the analysis within the supply-demand model. *Reactive* modes are ones in which the service offered is adjusted to changes in travel demand. Thus, a CTOL operator will add aircraft to routes with high demand and remove aircraft where demand is low. The result will be changes in the frequency of service and in travel costs. *Nonreactive* modes are ones in which service characteristics remain constant regardless of changes in demand. In STAR, this was assumed to be the case for auto and bus.

[18] Terminals include not only passenger facilities, but also runways, taxiways, and support facilities needed for vehicle operation.

characteristics of service). Then, through repeated supply-demand iterations, the model estimates travel volume and service characteristics for all the modes. This process is depicted conceptually in Fig. 11. Many of the STAR impacts are calculated directly as a result of this process. These include such items as annual passenger volume, cost per passenger mile, capital investment, and door-to-door costs. Other impacts, such as economic, noise, and pollution considerations require outputs from the supply-demand program for their computation.

As indicated above, many major modifications were made to the supply-demand program. These include development of an entirely new ground mode supply model, development of improved financial analysis procedures, correction of errors in the previous MITRE air mode supply cost model, correction of errors in the previous MITRE air mode travel cost calculation, development of an income travel model to apportion travel by income group, changes in program output to directly produce scorecard variables and data required for the economic impact analysis, the addition of procedures to produce punched card outputs in a form directly usable by the noise analysis programs for the noise impact analysis, and the ability to add runways to existing airports. Another significant modification was the development of a new approach to demand prediction more suited for California travel behavior. This was discussed in the previous paragraph on demand prediction. Table 2 summarizes Rand modifications to the supply-demand model.

In the supply-demand model, initial estimates of the door-to-door times and costs and the frequencies of service of all modes are used to predict demand for each mode between each pair of superdistricts. In response to demand, the operators of modes that have been specified as *reactive* decide how much and what kind of service they want to supply. Their menu of frequencies, times, and costs are combined with the unchanged menu of the static or nonreactive modes to derive new estimates of demand. Repetitive iteration along these lines simulates the adjustments of supply and demand to an equilibrium position and determines the volume of travel and the quality of service. This process is depicted in Fig. 12.

The supply models represent separate operators that control the

Feed in estimated
frequencies, times, costs

Start   Initial demands

Iteration   New supply
phase
                 New frequencies,
                 times, costs

                 New demands

Fig. 11--Supply-demand iteration cycle

DATA INPUTS

Input routines
• Data input processing
• Printout of data inputs

Nonreactive
Mode
Service
Estimates

Initial service estimates
for reactive modes

Multimode demand model

Estimated reactive
mode demands

Estimated nonreactive
mode demands

Reactive Mode Revised
Service Estimates

Iteration Control

End if complete

Estimated reactive mode demands

Air Mode Supply Model
• Service allocation model
• Cost estimation model
• Financial analysis
• Output routines

Ground Mode Supply Model
• Service allocation model
• Cost estimation model
• Financial analysis
• Output routines

Indicates areas of program
affected by Rand modification
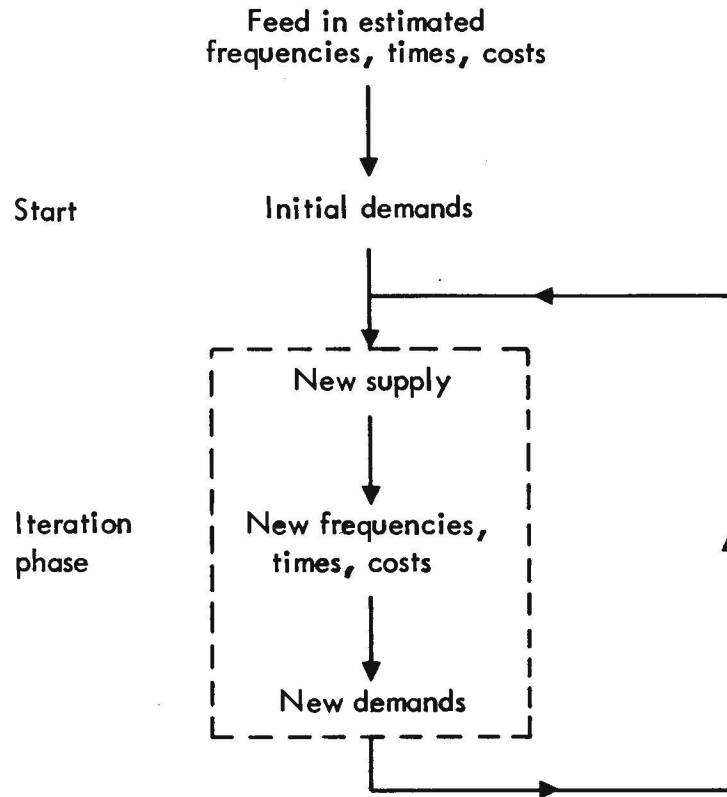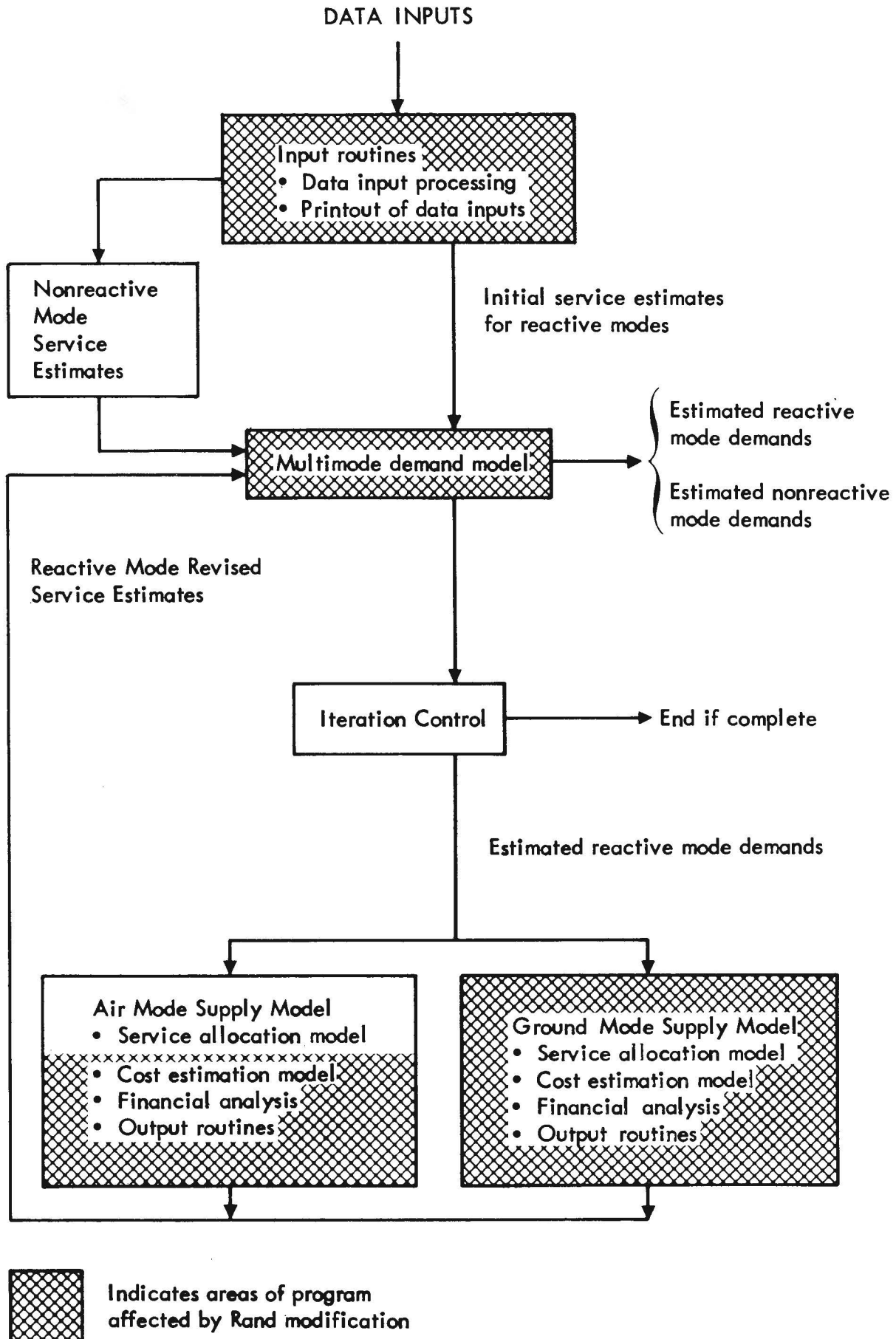
Fig. 12--Supply-demand program analysis procedure

Table 2

RAND MODIFICATIONS TO THE SUPPLY-DEMAND PROGRAM

o New ground mode supply model

o New approach for demand prediction and calibration to California data

o Development of improved financial analysis procedures

o Correction of errors in the air mode supply cost model

o Correction of errors in the air mode travel cost calculation

o Implementation of procedures to apportion travel by income-group

o Implementation of a runway option for use with existing airports

o Improved program output
   - Scorecard format
   - Data for economic analysis
   - Punched card output for direct use by noise analysis programs

services offered by their modes. The hypothetical operator of each mode sizes the service offered to the demand allocated by the modal split model and sets prices based upon his own independent optimization rules. An entirely new ground mode supply model was developed for use in STAR, along with the many other changes indicated in Fig. 12 and listed in Table 2.

Ground Mode Supply Model

Development of a new supply model was necessary because the previous model could not handle the loop networks required for the analysis. The previous model also had many other inflexibilities and restrictions that made it unwieldy for STAR use. It considered a relatively narrow range of frequency and routing possibilities, produced nonoptimal solutions, was overly influenced by peak period demand in fleet sizing, and was restricted in its choice of objective functions.

In addition to handling the STAR loops, the new model offers a more realistic simulation of ground mode system operations. The computation procedure developed for the model provides ground mode routing solutions which more realistically account for variations in demand between peak and nonpeak periods of travel and variation in travel among parts of the network.

The new model also has potential for expansion in capabilities for relatively small expenditures of effort. Thus, for example, the model could be extended to handle passenger transfers between vehicles. This additional capability might allow simulation and optimization of feeder operations or could be used to analyze some of the effects of intermodal cooperation.

Another example of the model's flexibility is its potential to use a wide range of possible objective functions. These could include maximizing profits, minimizing subsidies, maximizing passenger volume, achieving specified levels of demand, or achieving specified levels of subsidy or rates of return on investment. At present, three of these objective functions are implemented in the program. These include subsidized and nonsubsidized modes of operation.

For nonsubsidized operations, the model can be used to calculate levels of operation (number of vehicles, frequency of service, etc.) which provide the ground mode operator with a specified rate of return on investment.

For subsidized operations (typical of STAR ground mode cases), the model can be used to calculate levels of operation providing for either minimum subsidy or a specified rate of return on investment for a fixed amount of subsidy.

In developing the ground mode supply model, a review of the literature on programming and network analysis indicated that there were no standard approaches directly applicable to our problem. We thus had to develop methods that were tailored to the STAR requirements. After considerable evaluation, we determined two approaches that seemed to be potentially feasible for use in our study. These were a mixed integer programming approach and a marginal return approach.

We decided to implement the marginal return approach because of its inherent simplicity and consequent ease of implementation. It

offered potential expansion for use with feeder systems, it could be utilized with a wide range of objective functions, and it was computationally feasible for the STAR networks. The mixed integer programming approach possibly could be applied to more general networks, but required additional development for its implementation. Both of these approaches have considerable potential for expansion which should be utilized in future studies.

Financial Analysis

The supply-demand model specifies allowable transportation system revenues which provide the system operator with a "fair" rate of return on total investment after allowing for certain system costs.

In calculating his required revenue, the operator is usually allowed to include direct and indirect operating costs and depreciation. If his total investment includes debt financing, he may or may not be allowed to include interest costs. Taxes are usually included in the revenue calculation unless the target rate of return on investment is specified on a before-tax basis.

With the current version of the program, four options are available.

1. Permitted revenue includes direct and indirect operating costs, depreciation, taxes, interest paid on debt, fair return on investment.

2. Permitted revenue includes direct and indirect operating costs, depreciation, taxes, and fair return on investment. It does not include interest paid on debt.

3. Permitted revenue includes direct and indirect operating costs, depreciation, interest paid on debt, *before tax* fair rate of return on investment.

4. Permitted revenue includes direct and indirect operating costs, depreciation, *before tax* fair rate of return on investment.

In STAR analyses, we used option 2 with a 10-percent discount[19]

---

[19] This is an input and can be varied from case to case, although in STAR the same value (i.e., 10 percent) was specified for every case analyzed.

rate on total investment for calculating permitted operator revenue. The calculations themselves are based upon the following assumptions:

o Straight-line depreciation.

o Discount rate calculated each year on depreciated book value.

o Discount rate used to convert diminishing series of tax and debt interest requirements into an equivalent uniform annual series.

o Debt remains a constant fraction of depreciated book value throughout the life of the system.

o The discount rate and interest rate on debt remain constant throughout the life of the system.

Other Modifications

Procedures for using the other modifications listed in Table 2 are also described in R-1359/4-DOT. These include corrections made to the program, procedures to estimate travel by income and distance categories, the ability to add runways to existing airports, and modifications to program output. An annotated copy of the complete program printout is also included.

PREDICTION OF ECONOMIC IMPACTS FROM SYSTEM CONSTRUCTION: R-1359/5-DOT

This report describes procedures used to evaluate economic impacts resulting from construction of regional short-haul transportation systems. The procedures correspond to the economic analysis box on the general flowchart presented in Fig. 6.

Inputs required for this analysis are capital investment costs obtained from the supply-demand model and disaggregated cost data derived from exogenous sources. The end products of the analysis are the peak year construction impacts displayed on the STAR scorecard--i.e., peak year construction impacts on total sales, total employment, and total payroll for the region of interest. The analysis also indicates which economic sectors are most affected by construction activities.

During construction, large outlays will be made to acquire land, construct terminals and guideways, and manufacture equipment. These

expenditures, spread over as much as nine years, will create employment and generate income. In addition to the *direct effects* of specific construction expenditures, other impacts will extend indirectly through the entire regional economy as workers and companies directly involved in the project respend their additional incomes. These latter increments are referred to as *indirect effects*.

If the impacted region is experiencing high unemployment levels, additional demands for labor might be desirable. On the other hand, if resources are already fully utilized within the region, the additional expenditures are likely to result in inflation. If groups within the region are experiencing structural unemployment, estimates of direct employment impacts will provide insight into whether the additional employment will be available to members of those groups. A converse problem could also arise. Implementation of an improvement could result in relatively large shifts in demands for the products or services of a particular section of the regional economy, and "bottlenecks" might occur. The annual estimates of direct expenditures are useful in assessing this possibility.

In performing the analysis, we have to use an economic model for the specified region. The model used must be sensitive to both the direct and the indirect effects. Additional desirable properties are that the model be widely used and understood by analysts, be easy to implement, have relatively small and inexpensive data requirements, and provide a level of detail and accuracy commensurate with that produced in other parts of the study--neither too detailed nor too insensitive.

We found that the standard input-output models met these requirements for use in short-haul transportation studies of the STAR type. We thus developed our methodology around this type of model. An input-output model is available for every region in the United States. This is not true for regional econometric models, which are also more costly to implement, usually have exogenous forecast requirements, and vary considerably in structure. Simple employment multiplier models were rejected because of their conceptual and empirical difficulties. Also, no current estimates of employment multipliers (that were not based on another type of model) were available for the corridor area used in STAR.

Once the economic model is selected,[20] inputs have to be developed.
Input/output models require annual estimates of *expenditures* for re-
quired goods or services by economic sector-groupings of firms with
similar products and production relationships. Examples of industrial
sectors used in the STAR study are furniture and fixtures, primary
metals, and nonelectrical machinery.

The problem now becomes one of allocating the total capital invest-
ment expenditures produced by the supply-demand model into the required
industrial sector categories on an annual basis. This part of the anal-
ysis is performed in two steps. First, expenditure totals produced by
the supply-demand program are modified. Second, the modified totals
are allocated to relevant economic sectors and periods. In summary,
the overall procedure consists of the following steps:

o Select appropriate economic model (i.e., input/output model
available for region or other type if desired).
o Determine expenditure flows by economic sector and period.
o Appropriately modify and disaggregate total investment costs
as produced by the supply-demand program to produce the re-
quired expenditure data by sector and time.
o Calculate economic impacts utilizing the estimated sector ex-
penditures and the chosen economic model.

PREDICTION OF COMMUNITY ENVIRONMENTAL AND SOCIAL IMPACTS: R-1359/6-DOT

This report describes procedures used to evaluate community and
social impacts. The community impacts assessed include the amount of
land taken, the number of households displaced, the number of households
exposed to excessive noise, the amount of energy consumed, and the
changes in the amount of air pollution emissions. The social impacts
assessed include the distribution of the benefits (users) and disbene-
fits (e.g., displacement due to construction and noise) according to
major income and ethnic groups in the region.

---

[20]In the STAR study the model developed by Riefler and Tieboat
concerning the California and Washington economies was used[7].

The report is divided into several chapters, each of which describes procedures for calculating specific impacts as shown in Table 3. As previously discussed, distribution of travelers by trip purpose and by income is estimated using procedures described in R-1359/4-DOT. Figure 13 depicts the procedure followed in calculating community and social impacts.

The major part of this report explains the use of the noise impact evaluation methodology, which Rand developed to evaluate multimodal noise impacts. It also discusses energy and pollution analysis. This latter analysis consists of combining vehicle pollution and energy use factors (specified by the system design engineer) with levels of operation, as estimated by the supply-demand program, to calculate total emissions and energy consumption for the specified analysis cases. These calculations are performed by the pollution and energy program VEMISS.

The Rand noise methodology has been developed for both air and ground modes. It evaluates impacts with census data rather than just land area, as is usually done. It has the ability to handle a wide range of noise exposure metrics (e.g., NPL, NEF, dBA time exposure),[21] thus allowing the evaluation of analysis sensitivity to changes in metrics and criteria levels. It is a practical tool for regional analysis, and the census-tallying programs have many additional planning applications outside of the noise area.

The methodology consists of a set of sophisticated computer programs that can calculate the number of households impacted near airports and along ground routes. Utilizing the 1970 census and specifications of the number of air and ground mode operations for the region of interest, the number of households exposed to a specified noise criteria are calculated. This can further be broken down according to various data items on the census tape, such as income and ethnic background, thus providing estimates of impacts on various social groups.

The census programs themselves have a wide range of planning uses. Basically, they provide for census counts by category of census data and geographical boundary. Some applications involve calculating households displaced by right-of-way plans for mass transit, freeway

---

[21]NPL is noise pollution level, NEF is noise exposure forecast, and dBA is decibels on the A scale.

Table 3

COMMUNITY AND SOCIAL IMPACTS

| Impact	Volume No.	Chapter No.
Community: Construction Phase		
Land acquired (acres)	R-1359/6	3
Cost of land acquisition ($)	R-1359/6	3
Number of households displaced	R-1359/6	3
Community: Operating Phase		
Number of households exposed to excessive noise	R-1359/6	4,5
Amount of energy consumed	R-1359/6	6
Change in air pollution emissions	R-1359/6	6
Social		
Distribution of users by business and nonbusiness trip purpose	R-1359/4	
Distribution of users by income category	R-1359/4	
Distribution of noise exposure by ethnic groups	R-1359/6	4,5
Distribution of Noise exposure by income groups	R-1359/6	4,5
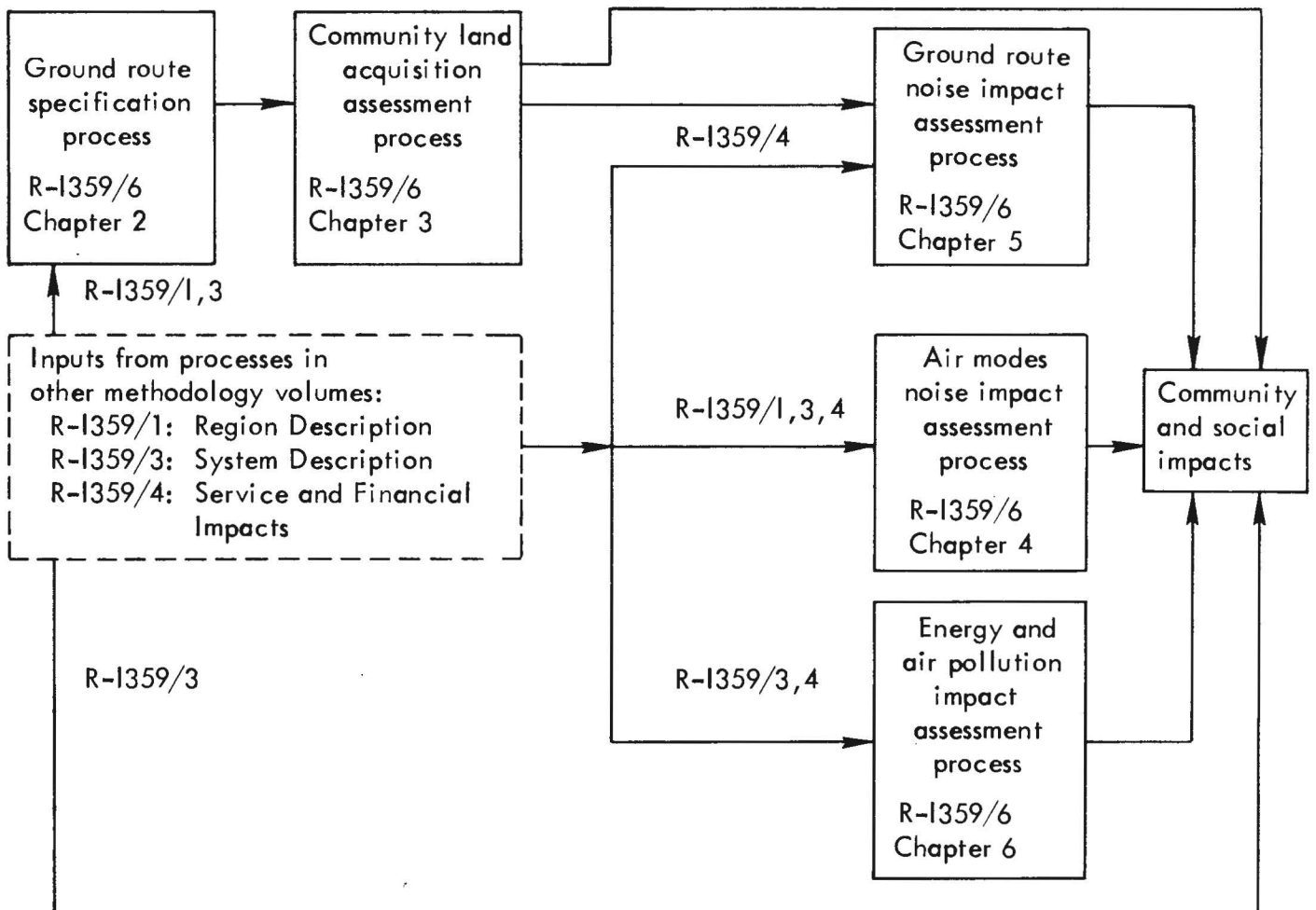
Fig. 13--Organization of community and social
impact assessment processes

construction, airport construction, or other projects. Other applications involve identifying populations within specified access regions for the design of air terminals, ground terminals, feeder service, and parking. Still other applications involve the design of regional boundaries according to desired census criteria. This is useful, for example, in designing tax regions, legislative regions, and planning regions.

An additional unique feature of the Rand methodology is its ability to provide a practical tool for performing regional analysis. Region, as used here, refers to an area that might contain several air terminals and many miles of ground route. In STAR, for example, the study region (the travel corridor between Sacramento and San Diego) contained 18 or more air terminals. Noise impacts had to be evaluated for each terminal for each of four distinct aircraft types for several levels of operation for each aircraft. There also were two distinct ground routes. Each was over 565 miles long and had several different levels of operation. With conventional techniques, such an analysis would be prohibitive in terms of the resources required. With the Rand methodology, however, such analysis becomes feasible and practical.

Table 4 summarizes some of these methodology features. The noise

Table 4

STAR NOISE METHODOLOGY

o   Evaluation of impacts with census data rather
     than just land area

o   Practical tool for performing regional analysis

o   Ability to handle wide range of metrics
     - Add new metrics with small program addition
     - Show sensitivity of results to metric change

o   Developed for both air and ground modes

o   Current version offers metrics
     - NEF
     - NPL
     - Time exposure (minutes at dBA level X or
        greater)

methodology programs are listed in Table 5. The basis for the noise calculation is indicated in Table 6.

Table 5

NOISE METHODOLOGY PROGRAMS DEVELOPED

Census Related

o CENSUS PROCESS PROGRAMS--Prepare NOISE EVALUATION census tape

o TALLY--Tabulates census counts within a specified contour

Noise Level Generation

o MODIFIED TSC NOISE EXPOSURE PROGRAM--Calculation of cumulative
                              (NEM)   time exposure profile

Air Modes

o MATRIX--Assigns on a regional basis flight track operations
           and calculates airport noise exposure levels

o CONTOUR--Calculates annoyance contour

o SUMMARY--Prepares regional noise impact report

Ground Modes

o GROUND MODES NOISE FILE PROGRAM--Selects and prepares segments
                                    for noise evaluation

o COMMUNITY NOISE EXPOSURE MODEL--Calculates noise impacts and
                                   prepares region report

One significant feature of the air mode evaluation procedure is the generation of a component exposure library and the use of the MATRIX program (see Table 5) to assign flight track operations. The modified TSC NEM (see Table 5) program is used early in the analysis to generate noise exposure grids for several generic types of flight tracks for each air vehicle to be used in the study. These exposure grids constitute the component exposure library. To evaluate a specific analysis case, the number of operations for each vehicle type for each

Table 6

NOISE EXPOSURE CALCULATION

o Directivity characteristics of vehicle (air or ground) utilized

o Time simulation of noise level used rather than just maximum value

o Cumulative time exposure profile calculated

o Allows conversion to arbitrary metric with just small changes in
   NEM and MATRIX

airport in the region are estimated by the supply-demand program. Us-
ing this information and airport description inputs, the MATRIX program
matches up operational requirements and assigns flight track operations
for all airports in the region. Then it uses the component exposure
library to calculate noise exposure grids for each airport in the re-
gion. Then the CONTOUR, TALLY and SUMMARY programs (see Table 5) are
used to calculate noise impacts. This process is depicted in Figs. 14
through 18.

Once the component exposure library is developed, the NEM program
need not be used again unless additional vehicles are added to the
study. Then the NEM program is used only to generate exposure grids
for the new vehicles. It does not have to be used for changes in levels
of operation, nor does it have to be used for evaluations at each air-
port. This results in significant resource savings and makes regional
analysis practical. This is illustrated by Tables 7 and 8. From these
tables it is clear that for the typical case described, analysis with-
out MATRIX would be impractical.

Figures 19 to 23 describe the ground mode noise evaluation proce-
dure. Figures 24 and 25 describe applications of the census impact
program.

The actual implementation of the methodology is organized into a
series of processes. Each process, documented in a single chapter

Table 7

TYPICAL REQUIREMENT FOR REGIONAL ANALYSIS

Unique airports	25
Aircraft types	5 short-haul, 1 long-haul
Number of operation levels	2-5
Number of metrics	1 or more
Other excursions - Noise abatement - Etc.	--

Table 8

RESOURCES REQUIRED FOR ANALYSIS

	With MATRIX		Without MATRIX (NEM Only)	
	Labor[a]	Computer Runs	Labor[a]	Computer Runs
A. 25 airports 1 short-haul type aircraft, 1 long-haul type aircraft 1 level of operation 1 noise metric	X	20 NEM[b] 2 MATRIX	5X	50 NEM
B. Same as A, but increase operation levels to 3	1.2X	20 NEM[b] 4 MATRIX	8X	100 NEM
C. Same as A, but increase operation levels to 5	1.4X	20 NEM[b] 6 MATRIX	11X	150 NEM

[a]Relative estimates.

[b]NEM runs of this type are much faster than the standard NEM runs for an entire airport because they involve 1 aircraft on a single flight track.

of R-1359/6, consists of a sequence of procedures, procedure being the basic unit of work. Usually, a single individual (no more than two) will be assigned to a specific procedure. Ideally, no more than one procedure will be assigned to any individual at any given time.

A procedure will usually require a couple of man-days (sometimes weeks) to complete. A process, on the other hand, is a collection of procedures and will usually require a couple of man-weeks (in some cases man-months) to complete. R-1359/6, a collection of processes, will usually require several man-months to complete.

The man time required to complete the analyses in this volume are more strongly dependent upon (1) the analyst's familiarity with the tools, (2) the analyst's background, and (3) the availability of data (including that from other volumes) and specific definitions for the cases to be analyzed.

DESCRIPTION OF CENSUS DATA PROGRAMS: R-1359/7-DOT; DESCRIPTION OF NOISE IMPACT ASSESSMENT PROGRAMS: R-1359/8-DOT

These reports describe computer programs developed for use in performing the STAR analysis procedures described in R-1359/1 and R-1359/6. R-1359/7 describes programs for preparing census data used in the analysis, while R-1359/8 describes programs used to evaluate noise impacts. The volumes describe the algorithms used as well as specific details of program implementation.

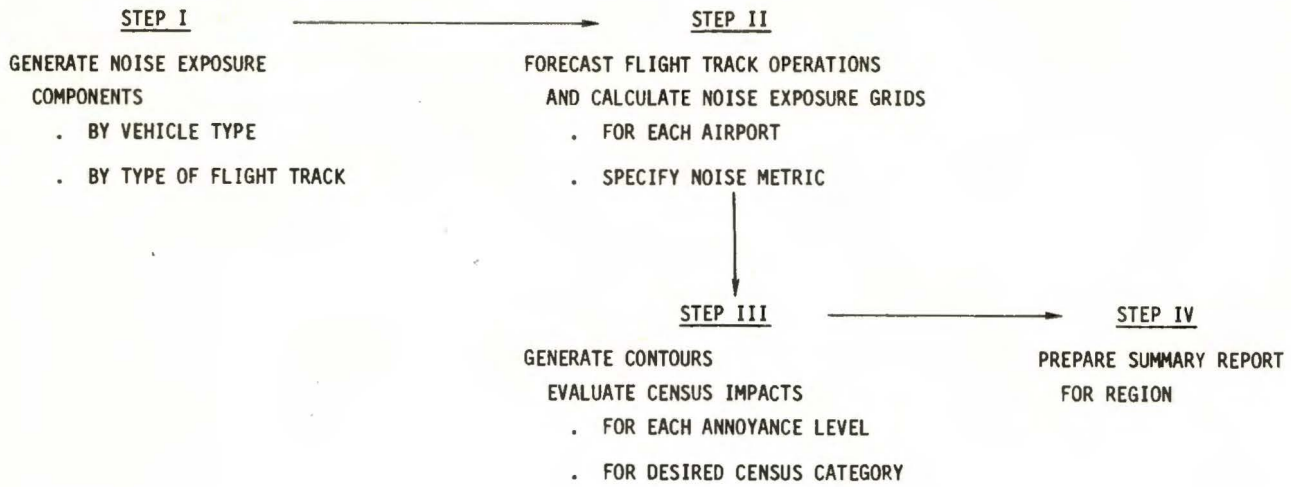REGIONAL ANALYSIS OF FUTURE OPERATIONS: OVERALL PROCEDURE
FOR AIR MODES

STEP I → STEP II

GENERATE NOISE EXPOSURE
COMPONENTS
. BY VEHICLE TYPE
. BY TYPE OF FLIGHT TRACK

FORECAST FLIGHT TRACK OPERATIONS
AND CALCULATE NOISE EXPOSURE GRIDS
. FOR EACH AIRPORT
. SPECIFY NOISE METRIC

STEP III → STEP IV

GENERATE CONTOURS
EVALUATE CENSUS IMPACTS
. FOR EACH ANNOYANCE LEVEL
. FOR DESIRED CENSUS CATEGORY

PREPARE SUMMARY REPORT
FOR REGION

Figure 14

STEP I
GENERATION OF NOISE EXPOSURE COMPONENTS

COMPONENT
EXPOSURE GRID

AIRCRAFT A ON FLIGHT TRACK TYPE X → NEM →

AIRCRAFT A ON FLIGHT TRACK TYPE Y → NEM →

AIRCRAFT B ON FLIGHT TRACK TYPE X → NEM →

AIRCRAFT B ON FLIGHT TRACK TYPE Y → NEM →
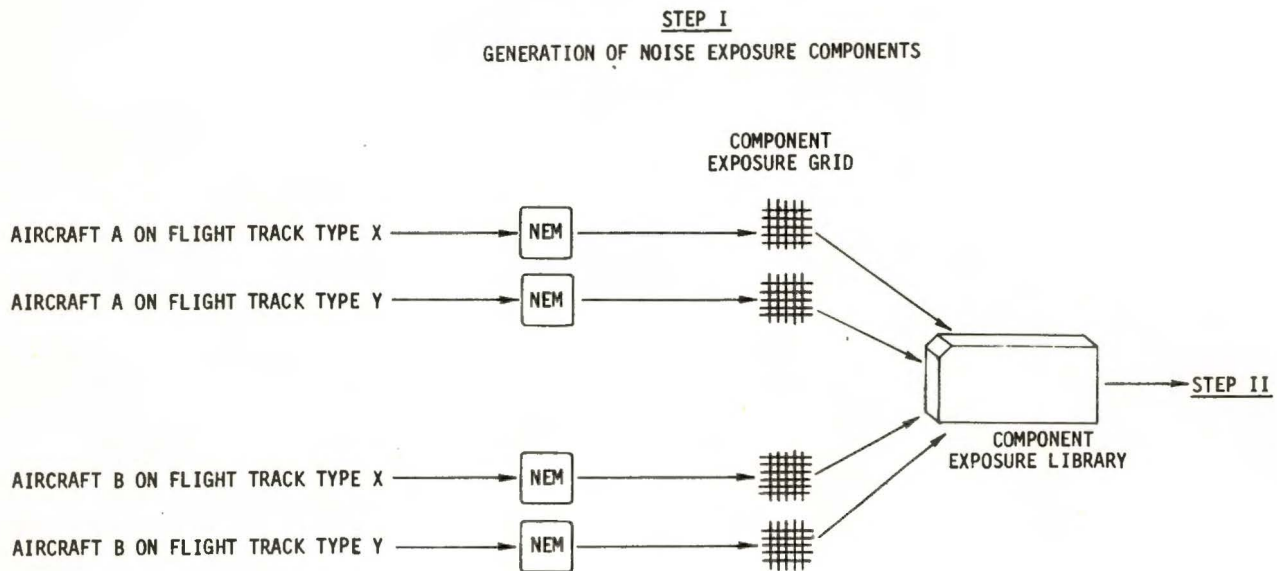
COMPONENT
EXPOSURE LIBRARY

→ STEP II

Figure 15

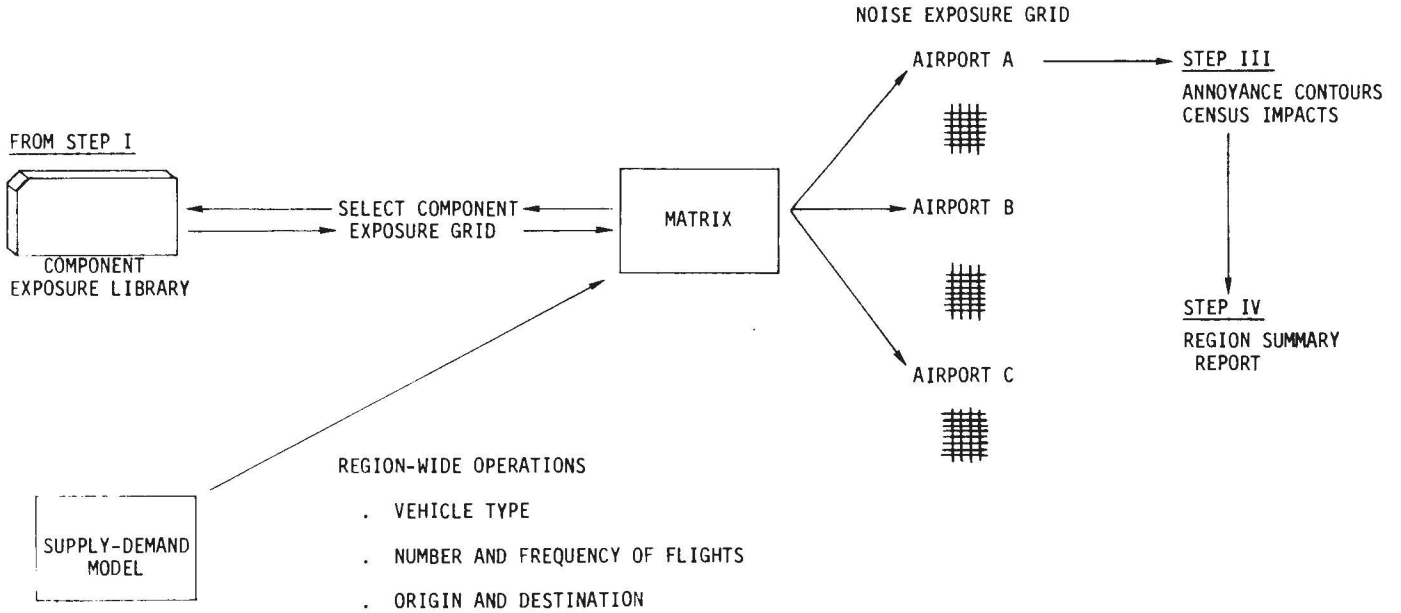STEP II

CALCULATION OF NOISE EXPOSURE GRIDS

Figure 16

STEP III

TALLYING CENSUS IMPACTS

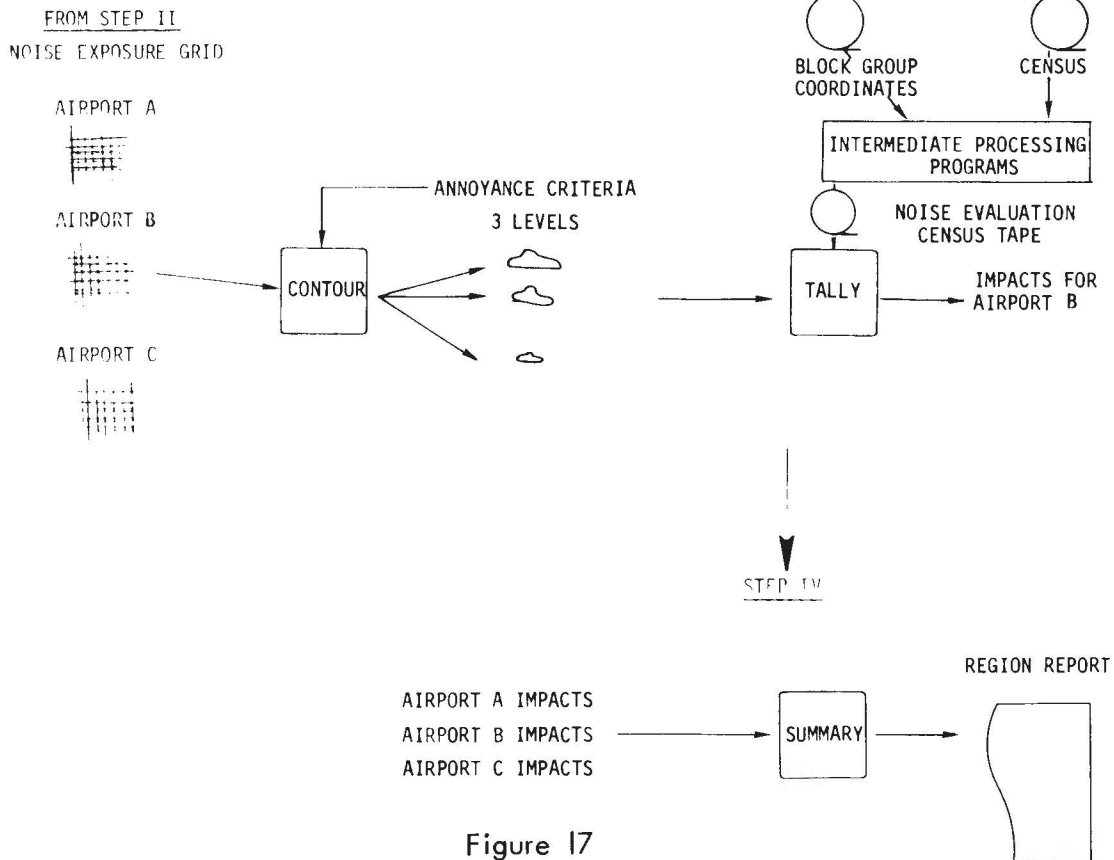Figure 17

REGIONAL ANALYSIS OF FUTURE OPERATIONS
(AIR MODES)

<u>METHODOLOGY FEATURES</u>

- PRACTICAL TOOL FOR PERFORMING REGIONAL ANALYSIS WITH "REASONABLE" BUDGETS

    - AUTOMATIC ASSIGNMENT OF FLIGHT TRACK OPERATIONS BASED ON REGION-WIDE OPERATIONS

    - UTILIZES COMPONENT LIBRARY TO MINIMIZE REQUIREMENTS FOR NOISE EXPOSURE CALCULATIONS AND INCREASE FLEXIBILITY

- WIDE RANGE OF NOISE METRICS POSSIBLE WITH SMALL MODIFICATION

- CENSUS IMPACTS

- REGION SUMMARY REPORT
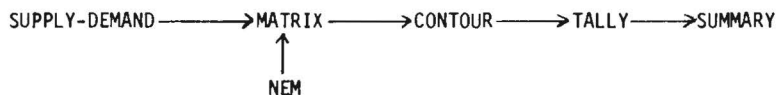
- ENTIRE ANALYSIS PERFORMED WITH COMPATIBLE SYSTEM

SUPPLY-DEMAND ⟶ MATRIX ⟶ CONTOUR ⟶ TALLY ⟶ SUMMARY
↑
NEM

Figure 18

REGIONAL ANALYSIS OF GROUND MODES: OVERALL PROCEDURE

<u>STEP I</u>

PREPARE SEGMENT ATTRIBUTE FILE

- INPUT COORDINATES FOR EACH ROUTE SEGMENT

- INPUT SEGMENT ATTRIBUTES

- TABULATE CENSUS DATA ALONG SEGMENT RIGHT OF WAY

<u>STEP II</u>

CALCULATE NOISE EXPOSURE LEVELS ALONG SEGMENTS WITH POTENTIAL NOISE IMPACTS

<u>STEP III</u>

CALCULATE CENSUS NOISE IMPACTS

- SELECT METRIC

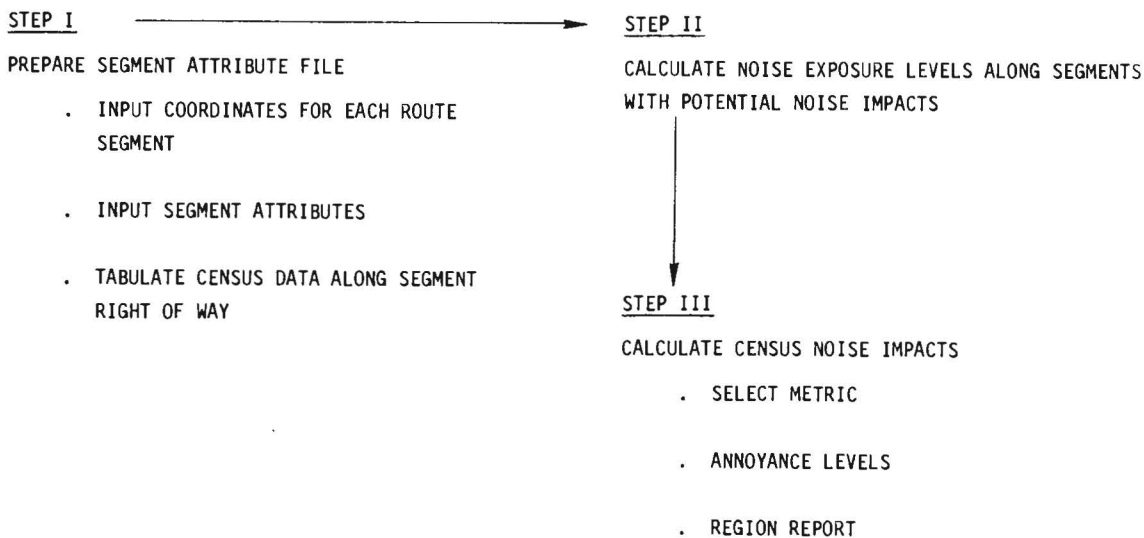- ANNOYANCE LEVELS

- REGION REPORT

Figure 19

STEP I

PREPARATION OF THE SEGMENT ATTRIBUTE FILE
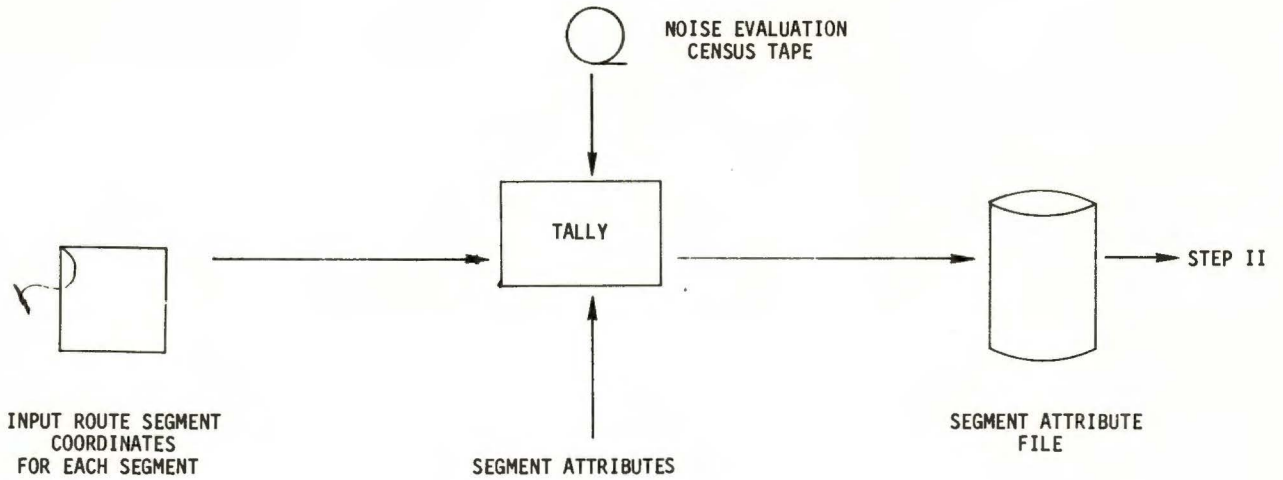
Figure 20

STEP II

CALCULATION OF NOISE EXPOSURE LEVELS

Figure 21

STEP III

NOISE IMPACT CALCULATIONS

ANNOYANCE LEVELS

COMMUNITY NOISE EXPOSURE
PROGRAM (CNEP)

METRIC SELECTION

REGION REPORT

NOISE EXPOSURE
OUTPUT FILE

SEGMENT SUMMARY
FILE

CENSUS IMPACTS

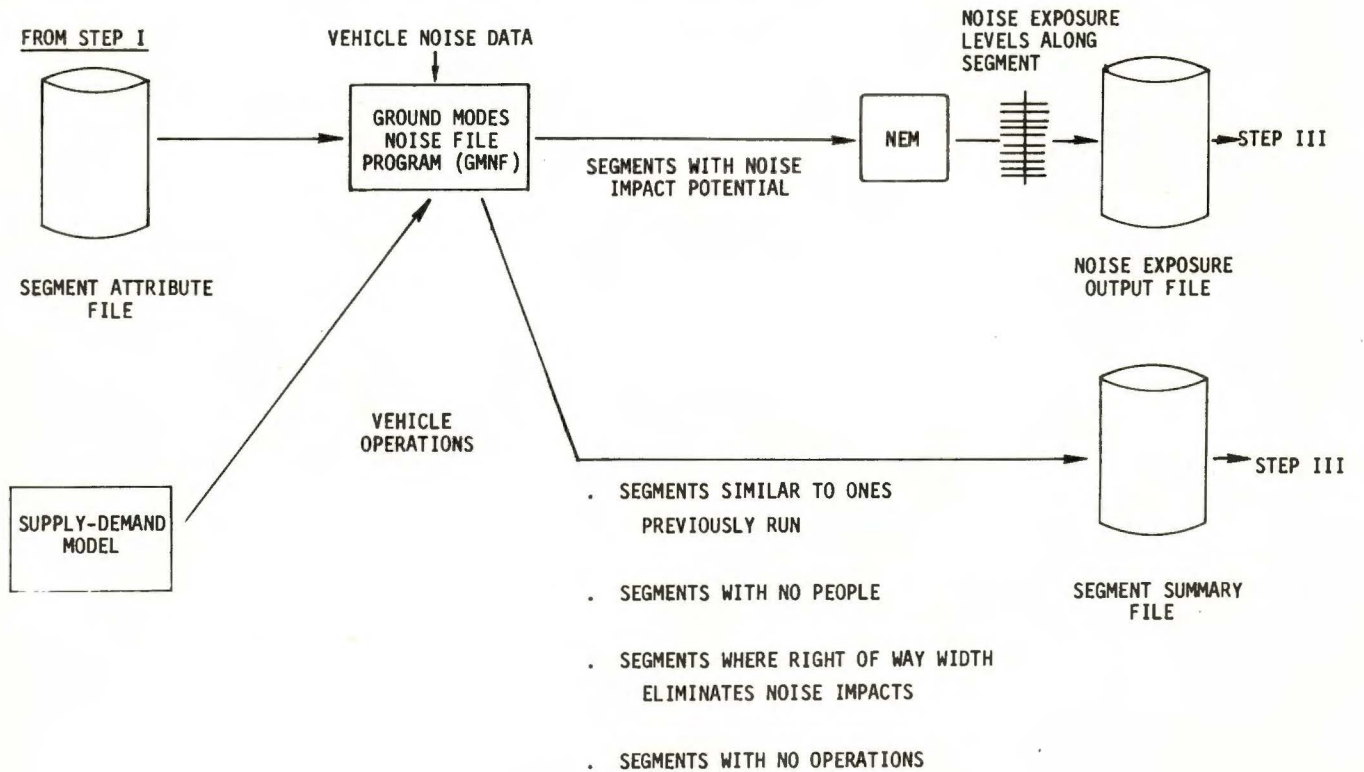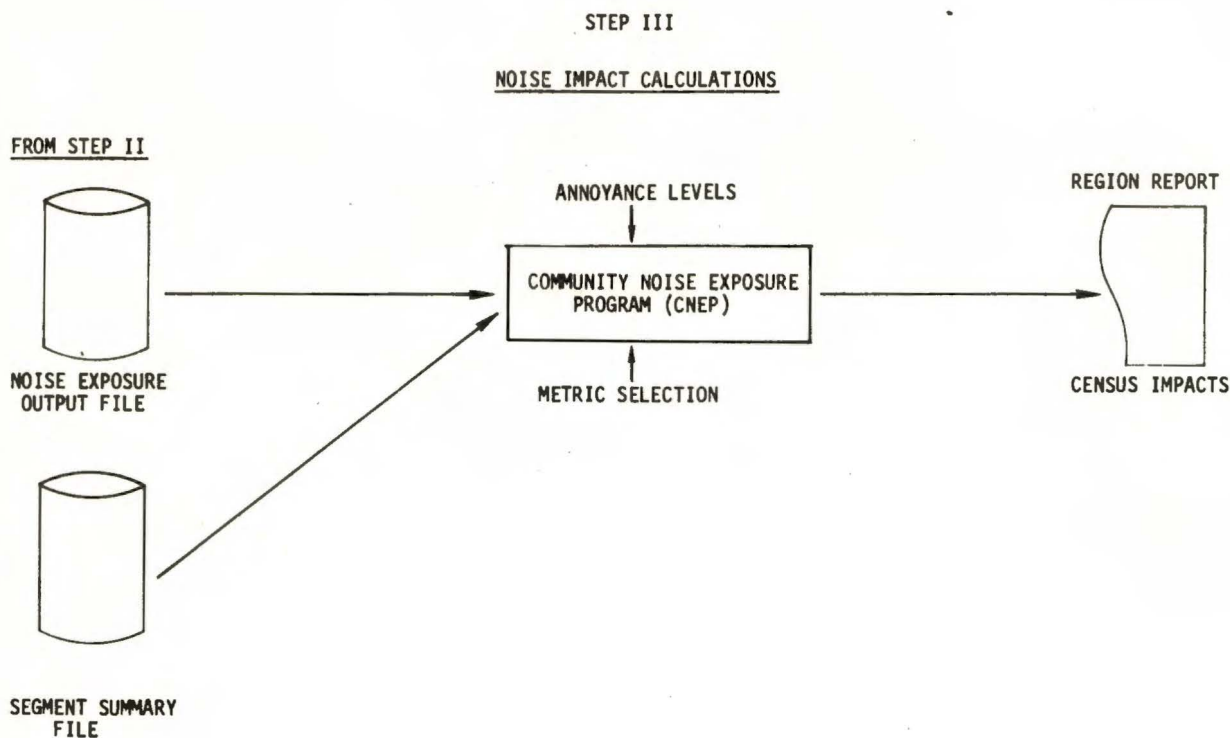**Figure 22**

GROUND MODE ANALYSIS

METHODOLOGY FEATURES

o CENSUS IMPACTS

o WIDE RANGE OF NOISE METRICS POSSIBLE WITH SMALL MODIFICATION

o SAME NOISE EXPOSURE PROGRAM USED FOR BOTH AIR-
    AND GROUND-MODE IMPACTS

o TABLET INPUT OF SEGMENT COORDINATES

·o REGION SUMMARY REPORT

o ENTIRE ANALYSIS PERFORMED WITH COMPATIBLE SYSTEM

TABLET → TALLY → GMNF → NEM → CNEP

↑
SUPPLY-DEMAND

Figure 23

OTHER APPLICATIONS

CENSUS IMPACT PROGRAMS HAVE WIDE RANGE OF POTENTIAL APPLICATIONS

- . Census counts by category and region boundary
- . Census maps

Figure 24

.

EXAMPLE APPLICATIONS

. DISPLACEMENT BY RIGHT OF WAY PLAN

- . Mass Transit
- . Freeway Construction
- . Airport Construction

. REGIONS OF SPECIFIED ACCESS LEVEL

- . Air Terminals
- . Ground Terminals
- . Feeder Service
- . Parking
    - .
    - .
    - .

. DEFINITION OF REGION BOUNDARIES ACCORDING TO DESIRED CENSUS CRITERIA

- . Tax Regions
- . Legislative Regions
- . Planning Regions
    - .
    - etc.

Figure 25

REFERENCES

1. *Recommendations for Northeast Corridor Transportation*, Volumes I, II, and III, U.S. Department of Transportation, September 1971.

2. *MITRE Multimode Transportation Model*, The MITRE Corporation, M-7124, June 1971.

3. Roberts, M. J., *AMCM: A Generalized Costing Procedure for VTOL and STOL Air Transportation Systems*, The MITRE Corporation, M-1674, 10 March 1971.

4. Ho, E. M., *Input Data Format Descriptions for the MITRE Multimode Transportation Model*, The MITRE Corporation, WP-8554, December 3, 1971.

5. Hoxie, P. A., *A Routing Heuristic*, The MITRE Corporation, WP-7387, May 5, 1971.

6. Roberts, M. J., and D. Goldman, *Air Modes Service Analysis in the NEC*, The MITRE Corporation, MTR-4112, December 1969.

7. Riefler, R., and C. Tieboat, "Interregional Input Output: An Empirical California-Washington Model," *Journal of Regional Science*, Vol. 10, No. 2, August 1970, pp. 135-148.