A COMPARATIVE ANALYSIS OF STATEWIDE TRANSPORTATION STUDIES

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This report reviews the 5 statewide transportation studies undertaken by Iowa, Wisconsin, Rhode Island, Connecticut, and California (study design). The studies are compared and rated as to the amount of effort expended in study design, data collection design, model development, forecasting and testing of alternatives, and implementation. Iowa spent 6 months and $9,000 of outside computer services to develop a future trip table and assign it to the present and committed highway system. Wisconsin spent 2 years and more than $100,000 in wages and computer services to develop and test alternatives and to develop a final state highway plan. Rhode Island and Connecticut spent more than 5 years and $1 million each to develop comprehensive statewide transportation studies that are strong in data collection, socioeconomic forecasting methods, and sophistication of the land use and travel models. These studies were grouped into classes that represent a cost level in which the effort is balanced among data collection, modeling, and plan development. The classes can be used as a guide by states considering a new study.

•STATEWIDE transportation studies based on statewide traffic assignments are a natural outgrowth of urban transportation studies. Ten years ago it was recognized that the urban areas lacked detailed planning information and studies that would determine what highway facilities should be built and where they should be located. At that time the rural areas had a large source of planning information from the highway planning surveys, which have been conducted since the mid-1930's, and were generally satisfied with the functional classification and needs studies, which recommended what highway facilities were needed and what their approximate locations should be. Urban transportation planning has come a long way in 10 years, and the states now need to make use of the procedures and models for comprehensive planning. These new tools applied at the state level should improve the present state functional classification and needs studies and lead to better decision-making.

Furthermore, interregional traffic patterns are in need of investigation as much as intraregional traffic patterns. The planning of an urban transportation network is deficient unless it takes into account the planning of interregional arterials leading into the urban area. It is believed that a good state transportation plan can provide the framework for good regional and local planning. A statewide transportation plan provides a means of coordinating capital improvements with the activities of other state agencies, and it provides a means for a balanced allocation of projects in the many regions and urban areas of a state. Furthermore, the goal of the state should be an efficient transportation system that will best serve the statewide movement of both persons and goods and promote desirable state development patterns.

To better understand what constitutes a good statewide transportation study, the author has selected for description 5 out of the 23 studies listed below:

Status	Study
Developed and tested future-year plans	Wisconsin
	Rhode Island
	Connecticut
	Delaware

Status	Study
Assigned future-year trips	Iowa Illinois Arizona Pennsylvania Michigan Minnesota
Assigned base-year trips	Missouri Tennessee California
Have started studies	South Dakota, Kentucky Oklahoma, Nebraska West Virginia, Georgia Wyoming, Florida New York, Mississippi
Selected for description	Iowa Wisconsin Rhode Island Connecticut California

The 5 states were selected because they have completed their initial study objectives, and their outputs are close approximations to completed statewide transportation studies. In addition, the studies were selected for comparative discussion purposes because they vary in degree of sophistication from the simple statewide traffic model completed in Iowa to a study design incorporating the systems analysis approach to be used in California in a future integrated statewide transportation study. The Wisconsin, Rhode Island, and Connecticut studies fall in between the Iowa and California studies. Although simple model techniques were used in Wisconsin, very good planning techniques were used in testing of alternative systems, selecting the final plan, and taking steps for implementation. Rhode Island and Connecticut are using sophisticated model techniques and are performing comprehensive statewide transportation studies that will also satisfy the requirements of the 1962 Federal-Aid Highway Act.

The author's opinions regarding the strong points and the limitations of the studies are discussed. A complete description of the respective studies is given in reports published by the respective states or elsewhere (1).

IOWA

Iowa completed the first known statewide traffic assignment (2). State highway department personnel performed the work between November 1963 and May 1964 and used about $9,000 in outside computer services.

Data on trips made by automobiles and trucks were obtained from the Mississippi Valley multiple screenline origin and destination survey (MVOD) conducted in 1959 and 1960. Trips recorded from the 132 interview stations were combined with data from 292 interview stations that were part of the external cordons of urban transportation studies. The data from these stations were edited, factored to ADT and to the 1960 base years, and combined into a statewide trip table.

In Iowa, trip ends were coded to cities and villages with place names. Each village with more than 150 people was made a separate centroid. The villages with fewer than 150 people were grouped with the nearest village with more than 150 people. This resulted in 855 internal centroids and 72 external stations at the stateline, a total of 927 centroids.

The base assignment network for 1960 included 10,221 miles of Interstate and state primary highways and selected county roads. The committed assignment network included these roads plus all proposed Interstate highways and all other completed and programmed improvements after 1960.

The zonal population was forecast to 1980 by using the step-down ratio method. A forecast of the statewide trip table to 1980 was made by the Fratar method. The projections of trips between all zones were based on the 1980 to 1960 ratio of population for each zone modified by an overall state factor for increased automobile ownership and increased travel projected for 1980.

Some experts consider the Fratar method to be weak in handling small volumes, unable to handle zero volumes superseded by new access or large population growths, and weak in contributing to the understanding of travel behavior. On the other hand, the Fratar method does well where the travel patterns do not exhibit large changes from the base year to the forecasting year, and the Fratar method is easy to apply. This appears to be the case in Iowa. The resulting assignment was used to prepare the 1965 Interstate cost estimate and to test alternative locations of I-35 in north central Iowa.

Major Good Points of the Study

1. The study accomplished its original objectives of obtaining a statewide traffic assignment for 20 years into the future that would show diverted traffic to the Interstate System.
2. In terms of cost effectiveness the study was outstanding. It was accomplished with 6 months of work and $9,000 in outside computer services.
3. The study was performed by highway department personnel. Therefore, they had full cognizance of the limitations and could make further assignments as needed.

Limitations of the Study

1. The trip table is missing most of the short trips, trips under 10 min in length, or an estimated 24 percent of the system vehicle-miles of travel.
2. Iowa did not develop or test any alternative highway plans. The only system tested was the one programmed for construction.
3. Iowa did not develop a transportation plan or relate it to other state facility plans.

The discussion on limitations refers to the study design and says in effect that Iowa did not go far enough with the planning effort.

WISCONSIN

The Wisconsin Statewide Transportation Study was begun in April 1964, and the main effort continued until about December 1967 (3, 4). It was undertaken by state highway department personnel. Many reports have been published that document the study very well.

The base data were from the MVOD survey conducted in 1959 and 1960. There were 186 roadside stations at which 350,000 interviews were conducted. An attempt at synthesizing the trips in the areas bounded by the screenlines was unsuccessful, and the study proceeded with the basic 1960 MVOD trip table.

Zones were developed on the basis of townships; each township having a population of more than 1,000 people was made a separate zone. This gave 570 internal zones. Counties in the adjoining states, other states in the United States, and provinces in Canada accounted for 24 external zones. Forty-nine additional zones represented the external stations for a total of 643 zones.

The selected network included 10,434 miles of Interstate and state trunk highways and about 4,050 miles of county, town, and other roads for a total of 14,484 miles.

The study staff used the 1980 population forecasts developed by the Wisconsin Department of Resource Development (DRD). Two population forecasts had been developed. One was based on employment forecasts, and a second was based on demographic trends by the "short reliable" method. One was a low forecast, and the other was a high forecast when compared with independent sources. In addition, DRD admitted that its procedure had resulted in an underallocation of population to zones of a suburban character. A rather arbitrary set of rules was developed in order to select population from either the employment-based forecast or the demography-based forecast or the mean of both

of them. In addition, these forecasts were on a county basis and had to be allocated to the zones. This allocation was done on the basis of the 1960 ratio of township to county population and did not appear to account for the different growth rates among zones. Some upward adjustment of population was made to the suburban zones by using the demographic forecasts. The original county forecast was to 1980, and the highway department extrapolated the forecast to 1990 based on the 1960-1980 growth rate.

The Fratar method was used to forecast the statewide trip table. For automobile trips, the growth factor was based on growths of population, vehicle-miles, and recreational attraction. For truck trips the growth factor incorporated employment and vehicle-mile factors.

The development and testing of alternative highway systems were very extensive. The concept of functional classification was used to develop a hierarchy of systems as related to the hierarchy of cities and regions served. The staff generated 16 planning schemes in an attempt to look at a wide variety of ideas on highway systems. From these schemes the staff developed 4 alternatives based on different mileages and different configurations of the functionally classified highways.

The highway system objectives were refined to standards that were the basis of traffic service tests and land service tests. One traffic service test consisted of an economic analysis of alternatives applying automobile user operation and time cost of $3.50 per hour. Total capital costs and total user operating costs of each of the alternatives were computed and used for comparison purposes. Other traffic service tests consisted of comparing vehicle-hours of travel on each of the alternatives and the percentage of long-distance trips occurring on the functional classes of highways within each alternative. In the land service tests, travel times were computed between metropolitan centers and other metropolitan centers, recreational areas, centers of highest assessed valuation, primary wholesale centers, and decentralized manufacturing zones.

A textbook rule is that the alternatives should be broad enough to include the optimum solution. Wisconsin realized that its 4 alternatives might not contain the optimum solution. Therefore, the staff developed and tested a theoretical all-freeway network (15 percent of total roads and streets) to obtain the upper boundary of feasible solutions. They discovered (much to their surprise) that the all-freeway system would have a lower total annual cost (construction plus user operating costs) than any of their other alternatives. This resulted in the development of the semifinal plan with increased arterial mileage and level of service and with a lower cost in comparison with the all-freeway network.

The desirable features of the alternative plans were combined into one plan, the semifinal highway system plan. The semifinal plan was then modified by suggestions from the central office and district offices of the highway department and the results of the traffic and land use evaluations. The final plan was checked for compatibility with activity plans developed by other state agencies. All of the tests indicated that the final plan was an improvement over the alternatives.

The final highway system plan was approved by the State Highway Commission on July 7, 1966. Steps have been taken for implementation. The final plan was first refined into a freeway-expressway plan. Next a guide for access control was developed. After that, specific corridor analyses were being undertaken in areas under intense development pressure for refining traffic forecasts, obtaining a specific location, and incorporating the location on the Official Map or taking other means for preserving right-of-way. Legislation was drafted on the reservation of right-of-way.

Major Good Points of the Study

1. The planning methdology was well formulated in the development of highway system alternatives and the refinement of objectives into traffic and land service tests. A 15 percent freeway network was tested to obtain the upper boundary of possible solutions. The study was well coordinated by obtaining review comments from the districts and other divisions within the highway department, was conducted within the framework of other state planning activities, and was made compatible with other state agency capital improvement plans.

2. After the approval of the final highway plan, the staff proceeded to take several steps toward implementation.

Limitations of the Study

1. As with any screenline study, the trips with both ends within the same grid are not obtained. The trip data become less accurate as one moves away from the screenline itself.
2. Trip card factors must be adjusted for those trips that cross more than 1 screenline. Usually there is no way to know which trips have been recorded more than once. Therefore, factoring may introduce some bias into the sampled data.
3. The MVOD screenlines were not coincident with zone boundaries. Therefore, some trips were intrazonal.
4. The recoding of the MVOD trips to zones resulted in 50,000 rejects when the data were edited. Some recoding involved estimates as to the correct zone of origin or destination.
5. MVOD stations were not located on all highways in the assignment network. This results in some missing interzonal trip data in specific locations.
6. The population projection (5) was rather simple and was constrained by ranges of projected populations with a set of rules for selecting the final value. A future study should apply more resources toward making good socioeconomic forecasts at the zonal level.

RHODE ISLAND

Rhode Island is a unique state with 1,000 square miles of land area and the Providence-Pawtucket metropolitan area, which contained 660,000 of the 860,000 population in 1960. In 1961 the Providence Area Metropolitan Study was started with a home interview sample of 5 percent within the city and 10 percent in the rural fringe. Standard truck and taxi surveys were also taken. A land use survey was made of the entire state during 1960-61 by the Planning Division of the Rhode Island Development Council. The detailed land use field notes were generalized into 7 land use categories of manufacturing, agriculture, residential, commercial, recreational, and public and semipublic uses.

The Rhode Island Comprehensive Transportation and Land Use Planning Program started on April 1, 1964, and the main effort ran until March 1, 1968 (6, 7). The total budget for the period was $998,156. The study had a policy committee and a technical committee. The federal members were the Federal Aviation Agency, Federal Highway Administration (formerly Bureau of Public Roads), and Department of Housing and Urban Development (formerly Housing and Home Finance Agency). The Rhode Island members were the Department of Public Works, Development Council, Department of Business Regulation, Transit Authority, and 3 city mayors. A 6 percent home interview was taken in the non-Providence portion of the state. There were 497 internal zones and 53 external zones for a 550 total. Since the entire state of Rhode Island is laid out with census tracts, the internal zones conformed with enumeration districts for ease of grouping by census tract. A uniform coding system for the land use was established, and data were collected concerning above-ground floor uses.

Trip generation and attraction equations were developed for home-based work trips, home-based shopping trips, home-based social-recreation trips, home-based other trips, and non-home-based trips. These equations included the following socioeconomic variables by zone: total population, automobiles, housing density, total employment, trade employment, and service employment. The gravity model was used for trip distribution.

Rhode Island has 4,380 miles of roads and streets of which 71.2 miles are Interstate, 750 miles are federal-aid primary, and 780 miles are other state highways—a total of 1,600 miles on the state system, and all of this constituted the assignment network. The highways were coded as expressway, arterial, and local.

The 1990 state population was forecast by using the cohort survival method (8, 19). A step-down procedure was used to determine zonal estimates. The zonal population

forecasts were checked against the holding capacities of existing amounts of vacant land in the zone, and modifications were made where necessary. Trends were used in projecting labor force, dwelling units, median income, and housing density.

Industrial land use was coded to 1 of 7 categories. Future industrial parks were ranked by priority based on services available. It was assumed that a certain percentage would be filled within each priority group for the forecast year.

Since the study's conception, the staff has been applying the same long-range planning techniques and data to solving immediate problems and high-priority needs. Specific projects completed by the staff include a preliminary design for a proposed bridge site on the Blackstone River, preliminary design for 5 interchanges, state poverty program study, forecast state electric power requirements, statewide plan for refuse disposal, statewide plan for water service, and statewide plan for historical preservation.

As a result of the findings of the study, Rhode Island has been very successful in obtaining various federal grants. A grant of $900,000 and a loan of $3 million were obtained from the U. S. Department of Housing and Urban Development to modernize the bus transit system in Providence. A demonstration grant was obtained from the U. S. Department of Transportation for a rail-bus vehicle project. A direct grant and a loan were obtained to purchase open space for recreational purposes. Another grant was obtained to develop a community civil defense shelter plan.

Major Good Points of the Study

1. The study has been successful in applying comprehensive urban transportation planning techniques to the entire state. This includes the collection and forecasting of socioeconomic data by sound planning techniques.
2. The study is popular with the local officials since it has stressed specific project planning services requested by the officials.

Limitations of the Study

1. The home interview data collected outside the Providence-Pawtucket metropolitan area was not used except to check the validity of the previously synthesized model.
2. The study is weak in evaluation of alternative highway systems leading to the development of an optimal transportation plan. Initially the state had relied on deficiencies to develop the future expressway and arterial plans.
3. The study used standard, well-documented procedures in all of its activities. The staff did this on purpose to avoid costly, time-eating research and to emphasize service to immediate problems. On the other hand, new and sophisticated planning techniques can also be put into a project control system. As the staff completes most of the basic studies, it is expected that consideration will be given to new areas such as the rail-bus demonstration project performed in 1968.

CONNECTICUT

On October 17, 1963, the Connecticut Highway Department and the Development Commission executed an agreement to do a statewide analysis of land use and transportation. At that time, the Commission had completed a statewide land use inventory. The Connecticut Interregional Planning Program (CIPP) was expected to cost more than $1 million, of which $606,000 was financed by a U. S. Housing and Home Finance Agency grant. The original study life was 3 years and was extended. Six general reports have been published (9, 10, 11, 12, 13, 14); technical reports are available on request. The study is composed of the following 5 major parts.

1. Goals and objectives—In conjunction with the home interview survey an attitude survey was conducted. The staff reviewed statements made by the legislature and mayors as reported in the newspapers. The attitude survey and public statements were used for the development of a comprehensive set of goals and objectives (9, 10) covering transportation, land use, housing, and recreation.
2. Economic base model—The competitive position of Connecticut in relation to 12 other nearby states was evaluated. A survey form was mailed to 2,000 companies, and

83 percent responded. In those 35 industries showing very high and very poor growth rates, interviews were conducted to determine more significant factors affecting the future of that industry. This resulted in an industrial accounts model to determine the employment in the basic industries and dependent employment in the related service industries for 25 industrial categories. This resulted in a state total forecast for employment, labor force, and population. The town growth distribution model grouped the 25 categories into 6 categories of manufacturing, retail, service-business, service-professional, construction, and other employment and distributed the 6 employment categories to the 169 towns. The zonal growth distribution model grouped the service-business and service-professional and grouped construction and other employment. The 4 categories of employment were distributed to zones. The population forecasts were modified based on the relative size of the total change in forecast employment.

3. Land use distribution model—The 1963 land use information collected by the Development Commission was incorporated into the study. The undeveloped land in Connecticut was inventoried. The potential for development was determined by measuring various site characteristics including location, accessibility, availability of water and sewer, soil type, slope, and drainage. The model takes state aggregates of population and employment supplied by the economic base model and distributes the aggregates to subareas. A simultaneous equation system was developed to allocate land uses to 4 economic sectors: manufacturing, service, unique locator (e.g., hospitals), and population (e.g., residential use).

4. Recreation model—A 1 percent sample of the automobile registrations was surveyed via telephone to obtain travel data for Sundays in August for the hours of 3:00 to 7:00 p.m. These data were used to develop a recreation model to determine demand in relation to accessibility of recreational areas. Connecticut was interested in evaluating the concept of providing adequate recreational areas within 25 miles of the cities.

5. Transportation models—Travel forecasting models were developed for 10-year increments beginning with the year 1960 and ending with the year 2000. Goods movements models were developed for railroad and truck. A highway priority construction model is to be developed.

Connecticut had a 1960 population of 2,500,000 spread among 169 towns and 2,800 enumeration districts. The state was subdivided into a 1,725-zone system and an 804-zone system. The zones were developed by using enumeration district boundaries and population, land use, natural barriers, and traffic assignment considerations. There are 52 external stations that, when added to state zones, result in a total of 1,777 and 856 in the respective zoning systems.

The network for the 1,777-zone system contained 9,100 miles; the 856-zone system contained 6,900 miles of highways. Both networks contained the state system of 3,700 miles and all expressway and arterial highways. The principal test network was the 1970 committed highway network.

Existing data from home interviews conducted in the early 1960's in the Waterbury Area Transportation Study, Southeastern Area Transportation Study, and the Tri-State Transportation Study (Connecticut portion) were used. The staff conducted a home interview (1 percent sample) in the remaining unsurveyed areas of the state. This resulted in 3,200 interviews of the total 8,300 interviews from all sources. Trip generation and attraction equations were developed from the home interview and the socio-economic data. The gravity model was used for trip distribution.

Data on goods movements by truck were obtained by interviews with truck owners and at roadsides at the state boundary stations. A 4-month sample of goods movement data by railroad was obtained from invoices from the New Haven and the Central of Vermont Railroads. The data included commodity, origin and destination, number of cars, weight in hundred pounds, and whether inbound, outbound, or local.

It did not appear that the development and testing of alternatives received the level of effort that the model development and other parts of the study received. One report (15, p. 15) states, "Of the main factors to be considered in determining the need for a new or expanded highway facility, the volume of traffic using the existing facility is generally accepted as the best indication of need." The report continues (15, p. 19),

"The 'committed system,' used as the base network, was considered to remain static for the purposes of determining future deficiencies." Later in the report, deficiencies are determined and two sketch plans, grid analysis alternate and network analysis alternate, are shown. Also 2 other figures, the composite of regional plans and Connecticut Highway Department long-range proposals, are added to the alternatives.

The state considers the committed network to have a high probability of being carried to completion. That is, it represents a highway system that is "constructed, under construction, or has financing authorized for construction and/or engineering and rights-of-way acquisition."

The committed system was loaded with 1970, 1980, 1990, and 2000 traffic. The results were analyzed, and plan improvements were added consecutively by decade taking into account, on a subjective basis, the increased accessibility from the previous improvements. This resulted in the Connecticut expressway test plan (15, Fig. 14). The composite of regional plans was tested by using CIPP forecast land use as well as the socioeconomic data supplied by the 11 active regional planning agencies. This was a coordinated effort between the Connecticut Highway Department and the regional planning agencies.

At present, it appears that the staff has limited itself to satisfying deficiencies. Alternatives should be developed on a sufficiently broad basis to cover the optimum solution. As an example, alternative transportation plans may be developed to serve the alternative land use plans and reflect different levels of service to regional centers within the state. To date the study has not applied its own transportation goals, such as "bring elements of the community closer to each other," and its objective, "reduce time and distance of travel." Also, the figure of $3 billion in highway needs for the future mentioned in the report, A Plan for the Future (Partial), has differed little from the figure of $3 billion of needs mentioned in the report of Klar and Resnikoff (16, p. 186) and in the report, The Long-Range Plan of Connecticut Expressway Network, January 1965. The state says that this has occurred primarily because most of the anticipated growth in the state is expected to occur in the southwest and central corridor. The central cities are expected to continue as major attractors in the future. This results in major corridors of travel emanating from the cities as well as connecting them.

Major Good Points of the Study

1. Connecticut has undertaken a comprehensive study that has included sophisticated planning models. The latest developments in land use distribution models appear to have been used. Supporting the land use model is the very detailed inventory of existing land uses within Connecticut. In addition to the information collected on present use, the study has collected characteristics of undeveloped land for future use.
2. The sophistication and the detail of economic analysis are equal or superior to any of the current statewide economic studies. Connecticut developed what it believes to be comparable to an input-output model of the state.
3. The goals for Connecticut appear to be well researched by the attitude survey and in newspapers. The goals also appear to be formulated and clearly explained in the reports.
4. One goal for open space, natural resources, and recreation is, "Provide recreation as near as possible to concentrations of population." The staff has mentioned during discussions the figure of 25 miles as being the desirable limit for providing adequate recreational opportunities for the residents of an urban area. This is very desirable.
5. Connecticut also discovered that its design-hour volumes were occurring on Sunday afternoon, between 3 and 7 p.m. Thirty and 40 percent of travel during these peak hours are for recreation and social purposes respectively. A recreational model was developed to provide forecast recreational travel that improves the information available for design purposes.

Limitations of the Study

1. A 1 percent home interview sample was insufficient to provide an origin-destination trip table that when expanded and assigned to the network would give a good comparison with average daily traffic. Since several zones in the rural areas had less than 30 interviews, they had to be combined with adjacent zones in order to develop valid statistical relations. In spite of this limitation, the use of the origin-destination information in trip generation, trip distribution, and traffic assignment resulted in a match of 93 to 95 percent between assigned volumes and average daily traffic on 4 screenlines and 3 urban cordons. The staff is generally satisfied with the sampling rate.
2. The development and testing of alternative plans has not received the level of attention that other parts of the study have received.
3. Although apparently the staff provides information to design, the work on the construction priority program appears to be suspended, and the state still appears to hold back in recommending a highway plan.

CALIFORNIA

In late 1964, a request for a proposal was issued by the California Department of Public Works, Division of Highways, for the development of a work program that would establish the content and specifications for a systems approach to the solution of California's basic transportation problems. Subsequently, North American Aviation, Inc., was awarded the contract for $100,000. The project resulted in a 5-volume study design (17).

The study design proposes to use the systems analysis approach. The transportation system would be one subsystem within the California system. The transportation model was defined in a familiar way with submodels of population, economy, land use, transportation demand, transportation simulation, and evaluation. Each submodel would be designed with interfaces with the other submodels within feedback loops. They would operate in small increments of time so that feedback can occur between the submodels and take account of the dynamic nature of the system and the interrelated effects. Each submodel would use the latest forecasting techniques, such as, an input-output model for the economy submodel.

The study design states that there would be a low probability of accomplishing the study for $5,932,000 and a high probability of accomplishment for $9,200,000 within a study period of 52 months.

There is disagreement as to whether the advantages of the proposed systems analysis tools are worth the additional costs above the costs of the traditional methods. The arguments, pro and con, are beyond the scope of this report. In the author's opinion a systems analysis approach, if undertaken, would be most applicable to a dynamically growing, complex state, such as California.

In any case, the Division of Highways has not taken any steps to improve or implement the study design. However, there was recognition by various personnel within the division that some form of statewide model was needed. In late 1969 the central office staff responsible for the urbanized area transportation studies was given the approval to develop a statewide model.

A 1966 statewide trip table has been synthesized by extending the trip generation and trip distribution models developed in the 5 large urban area studies: Los Angeles, San Francisco, San Diego, Santa Barbara, and Sacramento. The statewide model has 1,600 zones and a network including the state highway system of 14,215 miles plus additional feeder roads.

A recent publication (18) gives a later study design using the systems analysis approach. The Pennsylvania study design builds on the California design and the investigations undertaken by the Northeast Corridor Project. The recommended study for the proposed Pennsylvania Department of Transportation has an estimated cost of $7,150,000 during a 5-year life.

Major Good Points of the Study

1. The study has feedback loops to account for the interrelatedness between land use and transportation systems. Most studies realize that the building of transportation systems will in turn affect the land use development patterns; the staff usually attempts to guide the land use development by restricting transportation facilities to certain corridors. On the other hand, few studies have tried to take account of the magnitude of the effects on the land use pattern resulting from the new transportation facilities.
2. Individual person and commodity movements will be studied. This allows emphasis to be placed on improving terminals for intermodal transfers. It should also allow for a better match between person or goods movement requirements and transportation system characteristics.
3. The systems analysis approach appears to be best for incorporating the analysis of new modes. In Volume 4 (17), the consultant presented an example analysis of petroleum movements and duplicated the threshold value reached and the shift from truck to pipeline that occurred in 1965. Likewise it is believed that transportation demands can be matched with new modes of travel, such as short takeoff and landing aircraft and hydrofoil ships.

Limitations of the Study

1. The process is considered to be cumbersome since it is a "forward seeking" model in that it goes forward in time and relies on the output from each period to set the requirements for transportation facilities and to give inputs for the succeeding period. Simulation usually requires a lot of data and quickly uses up many hours of computer time and generates masses of data. Large volumes of output are usually obtained and has to be evaluated to ascertain that it is reasonable.

This iterative procedure appears to be the best method of population forecasting using the cohort survival method or similar technique. Also the iterative procedure appears to be the best method for economic forecasting using the input-output model.

On the other hand, the advantages are not certain for land use forecasting and the respective transportation system to serve the new land uses. An alternative is the "goal directed" approach that sets forth alternative plans for the future year and investigates "backward" to see what the demands will be.

2. The California study does not propose any methods for overcoming some problems. The first step in systems analysis is to define the mission or objectives of the system. Normally the transportation planner will use a benefit-cost ratio framework. But what about conflicting objectives in the areas of safety, air pollution, noise, amount of land removed from tax rolls, and level of service? The study design did not help the evaluator who must be able to put the objectives in a framework where the decision-maker can evaluate trade-offs.
3. A major flaw was that airline distance (17, Vol. 3) instead of true network distance was proposed for the transportation demand model (commodity demands). Airline distance is not a network dependent variable, and therefore changes in the network cannot influence the commodity flows.

CLASSIFICATION OF STATEWIDE TRANSPORTATION STUDIES

The statewide transportation studies based on statewide traffic assignments differ among themselves in the type and scope of problems they attempt to solve. They also differ in the amount of resources—personnel, budget, and available data—that can be applied to the study. Limited resources require that the problem definition be put in a narrower context than it would be were more resources available. After the scope of the study has been determined, a balance should be determined among the effort spent on data collection, model development, and final plan development. Administrators are usually interested in completed studies that come to conclusions, i.e., a recommended plan. Table 1 gives the differences among studies, which are grouped into 4 classes, and should aid new studies in achieving a balance among data collection, model development, and final plan development.

Table 1. Classes of statewide transportation studies.

Class	Objective	Procedures
Statewide traffic model, $100,000 or less, 6 to 18 months	To do system simulation using computer to better understand how system operates (results are used for functional classification and general planning purposes)	Zones and network are selected and coded by using standard procedures; models for trip generation and distribution are kept simple, i. e., usually no trip purpose breakdown, usually 1 but not more than 3 independent socioeconomic variables, and minimum O-D data
Statewide transportation study (highway), $100,000 to $500,000 (usually more than $200,000), 15 to 30 months, 6 to 12 personnel	To develop intermediate-priced traffic model based on O-D sample design; to obtain good information on trip generation and trip length; to evaluate alternative highway networks; to develop state highway plan	O-D sampling for internal trips is accomplished by multiple-screenline roadside interviewing, stratified, cluster sample of homes, telephone interviewing, or comparable procedure; models are developed by trip purpose, usually automobile (3-5) and truck (1-2); comparisons and calibration are made against ADT volumes; development of alternatives includes functional classification, scheme development, and testing
Comprehensive statewide transportation study, $500,000 to $1,500,000, 24 to 48 months, 10 to 25 personnel	To develop on statewide or regional basis comprehensive transportation planning process; to simulate person movements by mode of transportation; to evaluate alternate modes and networks; to develop state transportation plan	Elements and procedures are similar to those in comprehensive urban transportation studies, interviews are sufficient to develop trip table of interzonal person movements; studies include economic base model and land use model; within budget limitations, goods movements would be obtained and projected
Integrated statewide transportation study, more than $1,500,000, 36 to 60 months, 15 to 50 personnel	To apply latest techniques in systems analysis and operations research to statewide transportation planning; to study complete system of person and goods movement from origin to destination; to evaluate alternate sets of policies in regard to transportation system; to develop state transportation program	Procedures incorporate latest techniques in systems analysis and operations research; detailed person and goods movement from origin to destination are studied with emphasis on transfer and terminal points; models are iterative with feedback to account for results of different transportation policies

The different classes of studies are compatible with one another. They proceed from the simple studies to the more complex studies. The simple studies can be used as an educational device before a complex study is done. The initial study, a statewide traffic model, contains detailed zoning and detailed highway network development. This is the same detail that is used for the larger studies. In addition, the state-line cordon is common to all studies, and data are collected on through trips and interstate trips.

The second class of studies, the statewide transportation study (highway), could be extended to the other transportation modes, such as railroad, air, and waterways. In looking at the other modes of travel, one could make a detailed analysis at congested terminals.

The statewide traffic model is a study similar to the one undertaken by Iowa. It is applicable to a state with rural characteristics and static or slow economic growth. Also, it can be undertaken as an educational process where statewide planning is not very sophisticated. The framework of the study provides a basic zoning and network development for current and future use. The MVOD data used by Iowa probably cost $95,000 but consisted of existing information that was 3 years old when it was used. If data are collected, it is suggested that external-external (through) trip and external-internal (interstate) trip data be collected at a state-line cordon. It is recommended that internal travel be synthesized from existing data. In most cases, the travel forecasts will be based on the 1 variable—population. If additional socioeconomic variables are used, a second variable can be an economic variable to account for influences other than that of population (perhaps car ownership or employment), and a third variable can be recreation attraction (annual visitations to a zone), which accounts for activity in addition to both population and economic variables. The study should result in a functionally classified network and synthesized future traffic volumes. Other studies classed as statewide traffic models include those that have been completed in Arizona and Illinois and those that have begun in Oklahoma and South Dakota.

The statewide transportation study (highway) is similar to the study in Wisconsin. This study would be undertaken by states with moderate growth or states developing

separate studies for each of the tansportation modes. The state uses moderately priced O-D sampling techniques and moderately priced population and economic forecasting techniques. The state spends a considerable effort, perhaps one-third of its resources, on the last phase consisting of developing and testing alternative networks, developing the final plan, and taking steps for implementation. Most states currently undertaking a study are grouped in this category of statewide transportation study (highway). These include, in addition to Wisconsin, Delaware, Georgia, Kentucky, Michigan, Minnesota, Missouri, Nebraska, Pennsylvania, Tennessee, West Virginia, and Wyoming.

The comprehensive statewide transportation study is similar to those studies undertaken by Rhode Island and Connecticut and initiated by New York and California. Probably this study should be undertaken by states with wide urbanization or with adequate funds to obtain a complete trip table of interzonal person movements. This would normally be the first class of study to develop a general land use plan separate from the forecasts of socioeconomic variables and to use commodity movements instead of the number of trucks. A considerable part, perhaps one-third, of the resources should be devoted to the developing and testing of the land use and transportation final plans.

The integrated statewide transportation study is similar to the study design for California. This study looks at transportation demands in terms of the characteristics of the origin-destination, time requirements, and cost requirements for person movements and commodity movements. This study has the resources to look at very detailed movements and requirements at intermediate and final terminals. Again a considerable part, perhaps one-third, of the resources should be allocated to development of the land use and transportation final plans.

COMPARISON AND ANALYSIS

A comparison of statewide transportation studies of Iowa, Wisconsin, Rhode Island, and Connecticut points out the strong points and limitations of the respective studies. The comparison is only relative since the studies represent different levels of effort and therefore a different class of study as discussed in the previous section. Table 2 gives ratings of the studies based on accomplishment. The numerical ratings are defined as follows:

Accomplishment	Rating
High	3
Medium	2
Low	1
Nothing	0
Unknown	?

Table 2. Comparison of statewide transportation studies.

Major Parts	Iowa	Wisconsin	Rhode Island	Connecticut
Study design	2	2	3	3
Goals and objectives	0	2	2	3
Data design	1	1	2	2
Model development	1	1	3	3
Forecasting				
Population variables	1	1	3	3
Economic variables	0	0	2	3
Land use distribution	0	0	2	3
Testing of alternatives				
Transportation alternatives	0	3	1	1
Land use alternatives	0	0	?	?
Implementation				
Freeway-expressway plan	2	3	2	2
Access criteria, right-of-way	0	3	1	1

Note: The studies are all compared against a theoretical ideal study that, of course, does not exist, but the comparison has the advantage of illustrating the strong points and limitations of the studies.

Study Design

All studies had good study designs. In each study, a straightforward application of study resources was made in accomplishing the study objectives. Connecticut had a good study design in terms of innovative methdology and interrelating future population, employment, and land use distributions.

Connecticut developed and applied the critical path method (CPM) to keep the study on schedule and to efficiently employ the personnel who occasionally numbered more than 30. The study staff in Rhode Island spent considerable time during the initial phase specifying the problems and the goals, developing work elements, and analyzing work flow. The work flow analysis used the program evaluation and review technique developed by the U. S. Navy in scheduling personnel and activities. Rhode Island was probably the most successful in completing work phases on time.

Wisconsin developed and applied the CPM to keep its study on schedule for more than 28 months. It is believed that Iowa did not develop a detailed schedule since the intensive effort was during a short period, 7 months, and the number of personnel was small so they could have daily contact. It should be noted that the study design in Connecticut, Rhode Island, and Wisconsin was not a "fancy" prospectus that sat on the shelf but a CPM that was developed by the staff, in blueprint or technical report form, and revised on a regular basis.

Goals

Connecticut, Rhode Island, and Wisconsin developed an extensive set of goals and objectives. Connecticut did possibly the most work in goal development, and that is reflected in 2 well written reports (9, 10). Goals are discussed at the personal, city, regional, and state levels. The state goals are categorized as follows: economic, urban form, transportation, open space-natural resources-recreation, and housing.

Rhode Island's goals can be categorized as follows (6, 7): transportation; orderly land use development; solution to transit problem; and satisfy federal requirements for urban transportation planning, transit grants, and recreation grants. In addition, Rhode Island wanted to establish a continuing, cooperative, and comprehensive process for better master planning at the state and local levels.

Wisconsin developed a set of objectives for a safe, efficient, and economical highway system that is integrated with other modes and coordinated with land development.

Coordination

The studies in Connecticut, Rhode Island, and Wisconsin were cooperative, coordinated efforts. The Connecticut Highway Department (now the Department of Transportation), Development Commission, and Department of Agriculture and Natural Resources were joint sponsors. The regional planning agencies were major contributors of data and plans, and one alternative system was a composite of regional plans.

In Rhode Island, coordination was achieved by a policy committee and a technical committee. The committee membership included 3 federal agencies, 4 state agencies, and 3 city mayors. One particular goal was to conduct seminars for state and local officials concerning computerized planning tools and data banks.

The Wisconsin state highway plan was developed as one of several statewide studies being coordinated by the Wisconsin Department of Resource Development. The highway department coordinated efforts with the Southeastern Wisconsin Regional Planning Commission, which was responsible for a recommended system plan within its area. Other urban studies were coordinated since the state staff was also responsible for their development. Later planning in Wisconsin included the other modes.

O-D Data Collection

No state had the best data collection design. Rhode Island did home interviewing at the usual sample rate of 5 to 10 percent based on high to low density of dwelling units. This sample rate gave a valid statewide trip table of surveyed trips, but it was expensive. Connecticut used primarily a uniform 1 percent home interview sample. The

1 percent sample provided data for trip generation and trip distribution equations. It appears to be the best initial effort in developing a compromise between expensive large surveys and inexpensive surveys collecting very few data. Wisconsin and Iowa used the large source of existing roadside data. It was inexpensive, but the studies had to compensate for the limitations of the data.

New studies, which are not so urbanized as those in Connecticut and Rhode Island and which undertake a statewide transportation study (highway) as defined previously, are expected to use one of the following examples: Minnesota and Nebraska interviewed at urban cordon roadside stations in urban areas with 600 population (Minnesota); Delaware conducted a 10 percent telephone survey outside of Wilmington; and Kentucky is conducting a 1.75 percent mail survey based on vehicle registrations.

Model Development

Both the gravity model and the Fratar method appear to give satisfactory results if adequate data are available and the models are properly calibrated. In Connecticut and Rhode Island, trips were related to detailed breakdowns of population, employment, and land use. The trip distribution was by trip length frequency obtained from the home interview survey. The procedures were similar to those of urban transportation studies using the gravity model.

Iowa and Wisconsin used the Fratar method, which requires a complete or nearly complete O-D trip table for the state. The growth factors usually are simple; in Iowa and Wisconsin they were primarily based on population.

Connecticut and Rhode Island collected recreational travel data, and Wisconsin used a recreational growth factor. Recreational travel now determines the design-hour volumes on many rural highways, and its importance is growing as incomes and leisure time increase. Most states factor average daily traffic to design-hour volume because historical data are available on factors. However, weekday data are not similar to weekend data. If weekday data are factored to ADT, they introduce considerable biases in trip purpose, trip length, car occupancy, and O-D patterns. Therefore, other states may follow the examples of Connecticut and Rhode Island and collect recreation or weekend travel data.

Forecasting

It is considered that Connecticut had the most sophisticated efforts in forecasting with the economic base model and the land use allocation model. Rhode Island used the cohort survival method to develop a state forecast of population.

Although the procedures in Iowa and Wisconsin were simple, the population forecast was controlled at the state level, and allocation of future growth to urbanized areas and regions had to be realistic and represented difficult choices as to which areas would grow very little.

An economic base model patterned after those of Connecticut, Rhode Island, or another study is very desirable. Economic activity levels for future years provide a basis for future employment forecasts.

Instead of using a land use model, most states will be looking at future resource use, development patterns of cities and regions, and preservation of environmental areas. In highly urbanized states, land use is quite important in definition of intensity of use and specific category.

Testing of Alternatives

Wisconsin developed specific evaluation criteria from its highway system objectives, which were categorized as traffic tests and land service tests. The alternative highway plans were developed after consideration of many planning schemes and were based on different levels of service. Several traffic and land use tests were applied to the alternatives. In addition, an all-freeway plan was tested. The final plan was developed by combining the best parts of all the alternatives. The study staff developed a final plan that reflected a high level of service with reduced travel time for the long trips so the cities and major centers were brought closer together.

It appears that both Rhode Island and Connecticut relied on deficiencies in the committed system developed by comparing the design capacities against the future volumes. No reports were published showing other tests.

Implementation

It appears that Wisconsin has done the most extensive work in the implementation area. The Wisconsin freeway-expressway plan has a good chance for implementation since it is an outgrowth of the final highway plan. Guides for access type and spacing criteria and revised geometric design standards have been developed as a result of the planning process.

Wisconsin has refined the final plan by performing corridor studies in the rapidly growing areas of the state and at other critical locations. This will tie down the specific location of the highway and permit some progress in reserving future rights-of-way, pending legislative approval of proposed legislation. A priority programming method has been developed and is now being tested in selected areas to see whether it is politically acceptable.

Connecticut is undertaking corridor studies to determine the optimum mix of various transportation facilities to handle the forecast demands. Connecticut listed as a specific objective to develop a "priority plan" (16, p. 186), and this is expected in the future.

CONCLUSIONS APPLICABLE TO FUTURE STUDIES

From the previous comparison some conclusions can be drawn and inferences can be made for future studies.

Effort spent on the study design is well worth the time and money. The study design should include a schedule such as a bar chart, critical path method, or similar tool.

Goals should be available or established for all state activities, and a subset of goals established for the transportation system. The study staff should develop the study objectives and the problems that will be studied. This indicates the purpose of the study and, along with the transportation system goals, provides the planning framework for subsequent technical activities. The goals and study objectives should be further developed into a set of evaluation criteria or performance standards for alternative testing and plan development.

The data collection design is important. State-line stations should obtain data on interstate travel. Origin and destination surveys for internal travel should be designed to make cost-effective use of existing and new data and to obtain statistically valid relations between travel and socioeconomic characteristics. Comprehensive studies should use home interviews to collect person trip data for all modes. Studies at a moderate level of effort are expected to use mail, telephone, or urban cordon roadside interviews to collect vehicle trip data for highways. Finally, where money is available for several, single-purpose studies, it is recommended that one multipurpose study be conducted where possible. For example, a state-line cordon could collect data on interstate travel, tourism, recreation, and interstate truck commodity movements.

The gravity model will probably be used by most states to develop statewide trip tables from the relation between travel and socioeconomic characteristics including the trip length. The gravity model or Fratar method may be used where urban cordon data provide a statewide trip table.

Connecticut and Rhode Island provided good examples of economic base studies and population and land use forecasting in a comprehensive statewide transportation study. At the moderate level of effort, most studies will not analyze land use, but regional and city development trends should be investigated. At the moderate level of effort, the following socioeconomic variables or a subdivision thereof will probably be used: population, employment, retail sales, and recreational activity. For most forecasting, a range with low and high forecasts is better than a single point forecast because of the large number of unpredictable factors. An economic base study or some level of economic analysis is encouraged to provide good future employment figures.

Rhode Island undertook immediate action projects. The immediate application of new data and the planning techniques to immediate problems can generate the support of management. Of course the immediate application must be successful and a proper

balance should be maintained between immediate-action planning and long-range planning so that the long-range planning effort is not delayed.

The alternatives should indicate the range in investment levels; the low boundary is the present system plus committed improvements, and the upper boundary is (in my opinion) the improving of the arterials and major collectors, 10 to 20 percent of the total mileage, to a level of service comparable with principal arterials or freeways. To a lesser degree, alternatives should reflect different physical configurations.

The goals of the state should be served by the goals and objectives of the transportation system. The objectives of the transportation system should be further developed into evaluation criteria or performance standards. Tests of alternative systems using the criteria or standards should lead to a recommended plan that best serves the goals of the state and is economically justifiable.

Finally, the planning effort is wasted unless it leads to implemented improvements. One of the major phases of the study should be work on implementation.

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