DODOTRANS I: A Decision-Oriented Computer Language for Analysis of Multimode Transportation Systems

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•THIS PAPER summarizes the major features of a computer language and set of programs that have been under development at the Massachusetts Institute of Technology. There were two general objectives motivating this development, one substantive and one procedural: (a) the system should be policy-sensitive—that is, it should be able to predict the consequences of a wide range of alternative policies toward multimodal transportation systems in a theoretically acceptable manner; and (b) the system should support an analysis process in which the analyst explores a wide range of alternatives and amasses large quantities of information while seeking to develop his understanding of the policy issues in a particular problem. Elements of this general philosophy were reported in several early papers (1, 2, 3). The synthesis of these two general objectives was detailed more recently (4, 5).

The current system, Decision-Oriented Data Organizer-TRansportation ANalysis System (DODOTRANS), reflects this philosophy, elements of which were reported in earlier papers. DODOTRANS is policy-sensitive in that it analyzes multimodal transportation systems; can test a wide range of options; can predict a wide range of impacts; finds equilibrium of supply and demand in the network explicitly; and contains supply, demand, equilibrium, resource requirements, demand shift, and evaluation capabilities (although some are indeed very rudimentary).

DODOTRANS is designed to support an analysis process in that it has a command-structured problem-oriented language; stores data on secondary storage devices (disk) that can be addressed by names assigned by the user; logs the evolution of the analysis process to allow a wide variety of useful and interesting trade-offs; provides a flexible evaluation capability (6) and the "browsing" capabilities required for exploration of impacts among differenct groups (7); provides interface with mathematical optimization systems for use in searching for good alternatives; and is modular and expandable.

The implementation of this system has been gradual. The present version, DODOTRANS I, evolved out of several predecessor systems. The first was the M.I.T. Incremental Assignment Program, designed for experimentation with alternative traffic assignment procedures (8), developed by Martin for the IBM 7094 and the CTSS time-sharing system. The second step in this evolution was the development of TRANSET I, a subsystem of ICES, which is the Integrated Civil Engineering System (9, 10). TRANSET I is a problem-oriented language for traffic assignment, including incremental assignment and other procedures, and also a basic data base management system for transportation network analyses. TRANSET I and the later developments are all operational on the IBM System 360 series.

TRANSET I is the basic framework on which later developments have been achieved. TRANSET II (5, 11) extended TRANSET I to include additional capabilities for the analysis of multimodal networks, with a variety of policy options to be tested and impacts to be predicted. DODO (12) extended an early version of TRANSET II to include an elementary decision-oriented data structure, as hypothesized in the problem-solving process (PSP) model (2).

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DODO and TRANSET II have been combined, and significant new capabilities have been added to create DODOTRANS I (13, 14). This system includes the multimodal analysis models of TRANSET II, the PSP capabilities of DODO, and new demand models, greatly expanded technology models, and evaluation capabilities (15). These capabilities are detailed in the following section.

DODOTRANS is still an evolving system. At any time, there is one version of the system that is "frozen" in development and maintained in operational status for classroom, research, and field use. At the same time, several additional versions are serving as "test beds" for development of new capabilities and for experimental use by students and research staff. We see the DODOTRANS system as a "breadboard" on which we can experiment with new approaches to the analysis of transport systems.

CURRENT DODOTRANS CAPABILITIES

There are two sets of theoretical concepts underlying DODOTRANS. One is the equilibrium approach to transportation systems analysis (4), which is briefly summarized here. DODOTRANS represents one set of approximations to the equilibrium approach that makes it operationally feasible for application to substantive transportation problems. The other is the PSP model (4), which will not be reviewed here.

The transportation systems analysis problem can be expressed concisely in terms of the following variables, each of which is a collection of many data items:

T = specification of the transportation system in terms of the full set of available options—technologies, networks, vehicles, and operating policies;
A = specification of the activity system in terms of both exogenous characteristics, such as national population and economic trends, and controllable options, such as land use controls;
F = pattern of flows of passengers or freight, or both, in the transportation system;
L = service characteristics of a particular flow or set of flows—travel times, fares, comfort, and the like; and
V = volume of flows on the transportation network.

These variables can be used to specifiy supply functions S, which give the level of service as a function of the transportation options and the volume of flows, and demand functions D, which give the volume of flows as a function of the activity system options and the level of service:

$$L = S(T, V)$$

$$V = D(A, L)$$

The intersection of S and D within the constraints of T results in an equilibrium pattern of flows in the system, F, characterized by specific values of flows, V_1, and the levels of service, L:

$$F = (V, L)$$

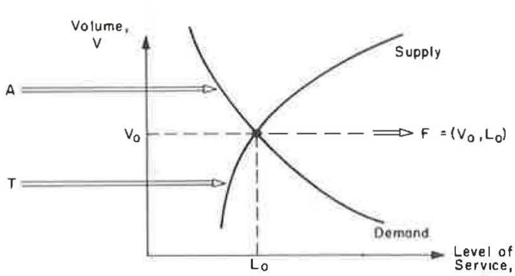


Figure 1. The equilibrium approach applied to transportation systems analysis.

These relationships are shown graphically in Figure 1.

There are many difficulties inherent in translating this conceptual framework to an operational transportation systems analysis procedure. A number of approximations to this framework must be made to implement an operational procedure. DODOTRANS represents one such set of approximations.

In terms of this theoretical concept discussed in the foregoing, DODOTRANS provides the capability of analyzing

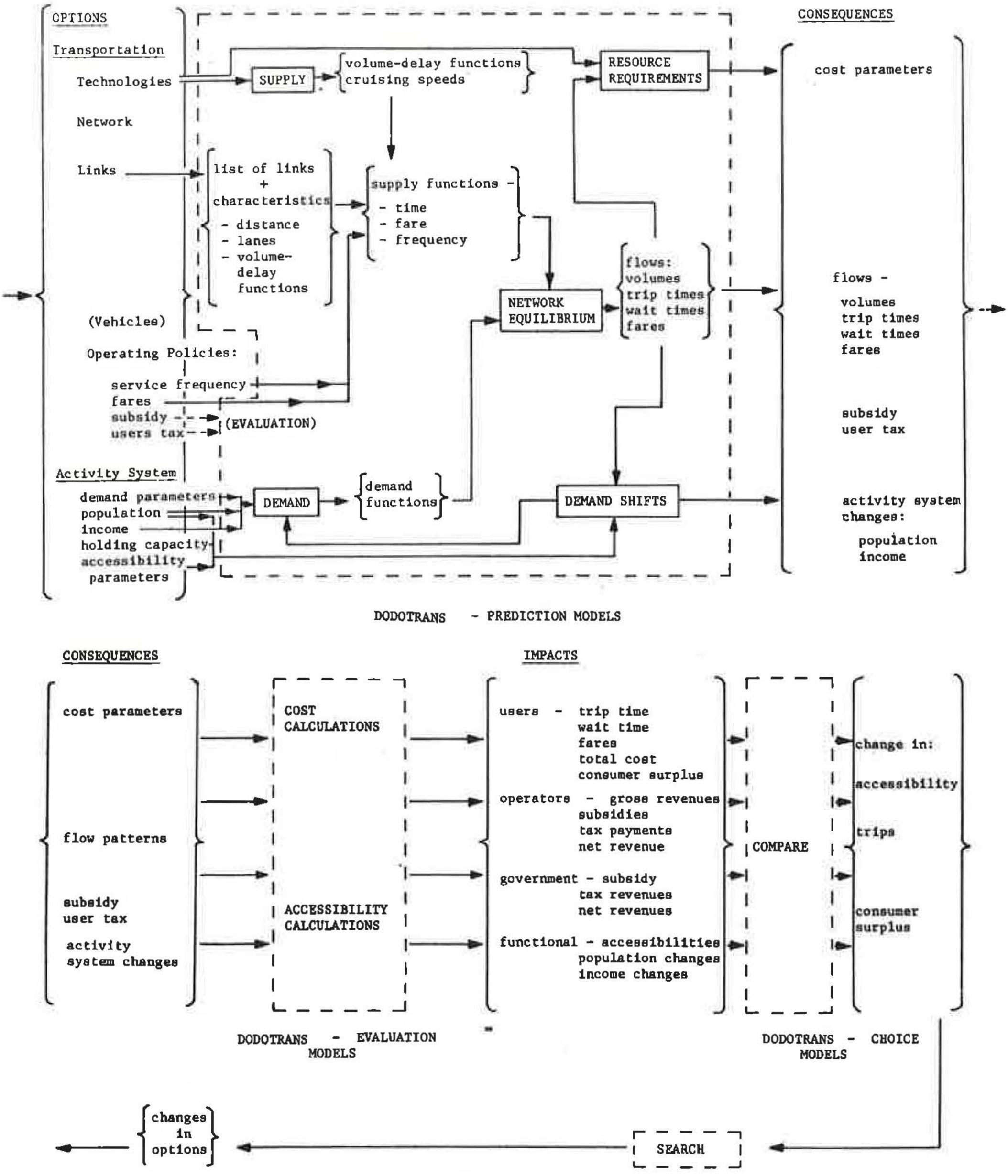


Figure 2. DODOTRANS and relation to equilibrium structure.

transportation problems by predicting supply and demand equilibrium in a multimodal transportation network. Because the nature of the transportation systems analysis problems can be described in terms of options, impacts, and the basic structure of the set of prediction models (5), it is useful to describe the capabilities of DODOTRANS in these same terms. Figure 2 shows the structure that underlies these capabilities.

Options

The basic options and the corresponding elements of DODOTRANS are as follows, when the simplest cost model is used:

1. Technologies—Options include volume-travel time functions, where each function gives travel time in minutes per mile per lane and as a function of volume in passengers per day (up to 14 volume-delay functions can be specified), and cost structure, where for each mode the fixed cost is in dollars per year and variable cost is in dollars per passenger mile.
2. Multimodal Network—Network options are specified by listing, for each link, its origin and destination node.
3. Links—Options for each link in the network include its length in miles, the number of lanes, and the volume-delay function.
4. Vehicles—There are no explicit specifications of vehicles.
5. Operating Policies—Options include frequency of service for each mode and pair of origin-destination districts in departures per day, fare for each mode and pair of origin-destination districts in cost per passenger, subsidy for each mode with total subsidy in dollars per year, and user tax for each mode as a percentage of the fare.
6. Activity System—Options include base year total population, per capita income, and population holding capacity for each district, and travel demand parameters as appropriate for each demand model.

When the single route cost model is used, the following basic options can be specified (16):

1. Technologies—Options include total route loading, unloading, and delay times; average route speed; and cost structure (labor, maintenance, and overhead costs associated with fixed facilities can be specified as fixed costs and in terms of units of capacity, actual volume, vehicle distance, and vehicle-hours).
2. Route Description—Options include actual volume, capacity, route distance, existing fixed facilities, and construction costs of fixed facilities.
3. Vehicles—Options include physical characteristics (payload, average load factor, and utilization rate) and cost structure (labor, maintenance, overhead, and fuel costs associated with vehicles can be specified in terms of units of capacity, actual volume, vehicle distance, and vehicle-hours).

When the network cost model is used, the following basic options, in addition to those listed under the first set of options, can be specified:

1. Links—Options include, for each link of the network, its fixed cost per year and its maintenance cost for a unit of capacity.
2. Vehicles—Options include physical characteristics (load factor, payload, utilization rate, parameters for estimating labor, maintenance, and fuel requirements) and cost structure (unit vehicle acquisition, labor, and fuel costs, and passenger service costs).
3. Operating Policies—Options include subsidies and taxes as lump sums by mode and based on vehicle use, link capacities, and number of passengers; and user tolls by route.

Impacts

The predicted impacts are grouped as follows:

1. Users—Impacts include total volume of passengers served by mode, by origin, and by destination; total trip time by mode, by origin, and by destination; wait time by mode, by origin, and by destination; and fare paid by mode, by origin, and by destination.
2. Operators—Impacts include total operating and governmental cost by route and by mode; gross revenue by mode, and by origin district; and net revenue by mode.
3. Government—Impacts include total subsidy by route and by mode, total user tax revenue by route and by mode, and net revenue by mode.
4. Physical—There are no physical impacts.
5. Functional—Impacts include accessibility by origin district and by mode; and population and income change by district.

Consequences

To determine these impacts, the following consequences must be predicted by the network equilibrium analysis:

1. Flow Volumes—Consequences include interzonal flow volumes (passenger trips) by mode, by origin, and by destination; and link flow volumes (total passenger flow for each link).

2. Levels of Service—Consequences include interzonal trip times by mode, by origin, and by destination; interzonal wait times by mode, by origin, and by destination (a fraction of the inverse of frequency of service, which is specified as input); interzonal total travel times (wait times plus trip times) by mode, by origin, and by destination; link speeds and travel times; and interzonal fares by mode, by origin, and by destination (specified as input).

3. Resource Requirements—Consequences include total fixed plus variable cost by mode, total user tax revenues by mode, and total government subsidy by mode.

4. Activity System Changes—Consequences include accessibility by mode and by district; and change in population and per capita income by district.

Prediction Models

The consequences described are predicted from the options using the prediction models briefly described in this section.

Demand Models—There are four basic demand model capabilities. One is specific, the other three are very general forms. The specific model is an early version of the Baumol-Quandt abstract mode model (17).

Conductivity demand models—The first general demand model form has been termed a conductivity model because it contains separate terms describing the ease of travel between origin and destination by each mode. The conductivity terms for competing modes are summed to provide a determinant of trips by all modes between an origin-destination pair. Also, the ratio of conductivity by one mode to the sum of conductivities by all modes is the mode split fraction for the given mode. In addition to the conductivity terms, the model includes a set of mode-independent terms. The mathematical form of the model is as follows:

1. Conductivity terms:

$$C_{kij} = a_k \prod_{\text{variables } l} V_{kijl}^{b_{kl}}$$

2. Mode-independent terms:

$$K_{ij} = \prod_{\text{variables } l} O_{il}^{d_l} \prod_{\text{variables } l} D_{jl}^{e_l} \prod_{\text{variables } l} W_{ijl}^{f_l}$$

3. Total trips:

$$TT_{ij} = K_{ij} \sum_{\text{modes } l} [C_{lij}]^g$$

4. Trips by mode:

$$T_{kij} = \frac{TT_{ij} C_{kij}}{\sum_{\text{modes } l} C_{lij}}$$

where

a_k = a mode-specific conductivity parameter;
b_{kl} = a mode-specific parameter associated with variable V_{kijl};
c and g = mode-independent general parameters;
d_l, d_l, f_l = mode-independent parameters associated with variables O_{il}, D_{jl}, and W_{ijl} respectively;
V_{kijl} = the l th variable describing a travel "price" between origin i and destination j by mode k;
O_{il} = the l th variable describing trip-generating characteristics of origin i;
D_{jl} = the l th variable describing trip-attracting characteristics of destination j;
W_{ijl} = the l th variable describing a mode-independent travel "price" between origin i and destination j;
C_{kij} = the conductivity for travel from i to j by mode k;
K_{ij} = the mode-independent determinant of travel from i to j;
TT_{ij} = the trip total, by all modes, from i to j; and
T_{kij} = the number of trips from i to j by mode k.

As implemented in DODOTRANS, the following variables are used:

1. For V_{kijl},

$$V_{kij1} = t_{kij}, \text{ travel time in minutes}$$

$$V_{kij2} = C_{kij}, \text{ fare in dollars}$$

$$V_{kij3} = (1 - e^{-hf_{kij}})$$

where h is a constant and f_{kij} is the frequency in departures per day.

2. For O_{il},

$$O_{i1} = P_i, \text{ the population in millions}$$

$$O_{i2} = Y_i, \text{ the average per capita income in dollars}$$

3. For D_{jl}, P_j and Y_j are as in 2.
4. For W_{ijl},

$$W_{ij1} = t_{bij}, \text{ the fastest travel time in minutes}$$

$$W_{ij2} = c_{bij}, \text{ the cheapest fare in dollars}$$

$$W_{ij3} = f_{bij}, \text{ the largest frequency in departures per day}$$

The conductivity model has, as two special cases, the McLynn model being used by the Northeast Corridor Transportation Study (18), and the Baumol-Quandt model as formulated for the prototype analysis (11). These special cases occur when the parameters have the following settings:

1. For the McLynn model, all f_l parameters equal zero.
2. For the Baumol-Quandt model, (a) all a_k parameters and the g parameter equal one; (b) all b_{kl} parameters would be the same for each mode k; and (c) the f_l parameters should be obtained from the "best" and "ratio" price parameters (indicated in the following by the b and r subscripts) normally associated with the Baumol-Quandt model as follows:

$$\text{time price—}f_1 = a_{t_b} - a_{t_r}$$
$$\text{fare price—}f_2 = a_{c_b} - a_{c_r}$$
$$\text{frequency price—}f_3 = a_{f_b} - a_{f_r}$$

Modal competition product form model—The second general model form has been termed a modal competition model because a set of parameters is provided that relates trips by one mode to "price" variables for competing modes. Another characteristic of the model is that variables in the model are combined using a single operator, multiplication.

The mathematical form of the model is

$$t_{kij} = a_k \prod_{\text{variables } l} O_{il}^{b_{kl}} \prod_{\text{variables } l} D_{jl}^{c_{kl}} \prod_{(\text{modes } m)} \prod_{(\text{variables } l)} V_{mijl}^{d_{kml}}$$

where

a_k = a mode-specific general parameter,
b_{kl} and c_{kl} = mode-specific parameters associated with variables O_{il} and D_{jl},
d_{kml} = a doubly mode-specific parameter associated with variable V_{mijl} (it indicates how trip-making by mode k will change due to changes in travel "prices", l, for mode m), and
O_{il}, D_{jl}, and V_{mijl} = variables with the same definitions as for the conductivity model.

As implemented in DODOTRANS, the variables used for O_{il}, D_{jl}, and V_{mijl} are the same as for the conductivity model. The product form of the modal competition model has the same characteristics as the Kraft-SARC demand model (19).

Modal competition summation form model—The third general demand model differs from the modal competition product form only in that the model terms are summed rather than multiplied together. The mathematical form of the model is

$$T_{kij} = a_k + \sum_{\text{variables } l} b_{kl} O_{il} + \sum_{\text{variables } l} c_{kl} D_{jl} + \sum_{(\text{modes } m)} \sum_{(\text{variables } l)} d_{kml} V_{mijl}$$

where the variables and parameters have the same definition as for the product form model.

As implemented in DODOTRANS, the variables used for O_{il}, D_{jl}, and V_{mijl} are the same as for the conductivity model. The summation form of the modal competition model has a simple structure useful for teaching purposes.

Supply and Resource Requirements Models—There are three basic capabilities. In one formulation the supply models are external to the computer programs. Hand calculations and engineering judgment are used to develop the basic functions required: cost coefficients for each mode, volume-delay functions, and cruising speed estimates. These are then input explicitly to DODOTRANS as data.

A second model handles a wide variety of cost components (16) and is very useful for parametric exploration. However, at present it is restricted to a single link at a time. The input is a number of variables describing the costs and required amounts of direct labor, maintenance, overhead, and fuel; the costs of vehicles and fixed facilities (supporting way and stations or terminals); the characteristics of the route; the design capacity and expected traffic volume; and the required amount of fixed facilities. From these variables the desired cost is computed.

This model treats a number of measures of the cost of a transportation system. Each of these is figured in units of dollars per year. The most obvious measure is total cost, that is, total yearly operating costs plus the yearly payment on investment. From this, two averages can be computed. The first of these is based on the capacity of the system; that is, average cost equals total cost divided by capacity in passengers per year or tons per year. The second average is based on actual volume: average cost equals total cost divided by actual volume in passengers per year or tons per year.

Another cost is one that is used a great deal in economic analysis, marginal cost. As used by the model, the marginal cost is the change in total cost for one additional unit of capacity or, in other words, the cost of that additional unit of capacity.

Corresponding to these four costs, four others take into account only the cost of investment in fixed facilities: total investment cost, average investment cost based on capacity, average investment cost based on actual volume, and marginal investment cost. In the calculation of these costs, operating costs are ignored and only investment costs are considered.

The model computes costs based on the number of passengers or tons of freight carried over a route. Of course, the number of passengers or the amount of freight carried will vary along the route, but there are two ways that this problem can be handled. The first method is to use an average number of passengers or amount of freight over the route. The second is to treat each link of the route separately. The latter method requires more computation but does not require an average payload figure and provides more detailed information.

A third model has a less flexible cost structure, but is capable of operating over an entire network. Resources consumed and corresponding costs are predicted, as well as minimum fleet size required.

The differences between the second and third models are as follows:

1. The second model only deals with one route, a single link over which one vehicle type of one mode may travel. The model must be iterated externally to handle more than one link, route, vehicle type, or mode. This model handles a large number of links, routes, vehicle types, and modes automatically. Each mode of the origin-destination combination generated in DODOTRANS becomes a route to be analyzed in the model. For each route, a vehicle type is specified. A number of parameters and costs may be specified by vehicle type. Also, each route is composed of a number of links, each of which may be described by a number of parameters and costs.
2. Vehicle requirements are determined to meet predicted demand, or a prespecified frequency of service, whichever requirement is greater. In the second model, frequency is not relevant; vehicle requirements are determined to utilize fully the available route capacity or to meet the specific demand.
3. A number of output measures are provided so that available empirical data on cost and on the constants used to calculate resource coefficients can be used with little adjustment.
4. The effects of governmental actions, in terms of taxes and subsidies collected from transportation operators, may be considered using the model. Operator costs due to taxes and subsidies are kept separate from costs due to technologies, but they are included in the model.

Network Equilibrium—The approach for computing equilibrium flows in the multimodal network is an incremental-loading traffic assignment procedure with variable increment, which is consistent with the demand model used.

Demand Shifts—An extremely simple model for computing the distribution of population and income is provided. The growth of each district in the region is computed as a weighted function of accessibility, present population, holding capacity, and an exogenously specified regional growth rate.

Evaluation

The impacts on the various groups are determined from the predicted consequences. In order to evaluate alternative systems, it is necessary to aggregate these consequences to produce various overall measures of the impacts of each alternative. The following evaluation "models" are, with the exception of accessibility and consumer surplus, simple summations over zones or modes, or both. (Accessibility and consumer surplus are computed consistent with the demand model used.) That is, where aggregate measures of impact are constructed, each group is weighted equally; e.g., all modes, origins, and or destinations are weighted equally when passenger hours or total fares or revenues are summed to various aggregate levels. Some of these measures

are directly specified as input (e.g., subsidy); others are functions of the predicted flow patterns.

1. Users—Measures include (a) total trip time by mode, by origin; by mode; system total; (b) total wait time by mode, by origin; by mode; system total; (c) average travel time by mode, by origin; by mode; system total; (d) average fare by mode, by origin; by mode; system total; and (e) user total cost—for specified utilities (relative weights of trip time, wait time, and fare) a weighted total cost is computed and aggregated by mode, by origin; by mode; system total.
2. Operators—Measures include (a) gross revenue from user fares by mode, by origin; by mode; system total; (b) gross revenue from government subsidy by mode; system total; (c) gross payment to government via user tax by mode; system total; and (d) net revenue by mode; system total.
3. Government—Measures include (a) subsidy to operators by mode; system total; (b) user tax revenues from operators by mode; system total; and (c) net revenue by mode; system total.
4. Functional—Measures include (a) accessibilities by origin, by mode; by origin; by mode; system total; (b) population change by zone; and (c) income change by zone.

These component and aggregated measures can be used in evaluating such comprehensive objectives as regional growth pattern, income distribution, fiscal feasibility, and political feasibility.

A flexible evaluation capability is provided that builds on the PSP structure. The basic procedures outlined in the PSP model and implemented in DODOTRANS are given in the following:

1. Generate alternative actions for solving the problem.
2. Predict the consequences of each action with the aid of a set of predictive models—the equilibrium model and related models.
3. Evaluate the consequences (impacts) of each action by using an evaluation model that transforms predicted consequences into normative goal performance terms or valuations.
4. Generate a preference ordering of the actions based on their relative goal performance.
5. Examine the best action as indicated by the preference ordering. If it satisfies all of the constraints of the original problem, or if resources for the analysis have been exhausted, implement it in the real world. Otherwise, search for new alternative actions and repeat the process.

The evaluation model in DODOTRANS is based on the concept of a goal fabric (6). A goal fabric is a set of goal variables that are defined in terms of arithmetic operations performed on basic consequences. The basic consequences are the outputs from the predictive models, e.g., fare, frequency of service, travel time, and trips, each of which may have different values for each route in the system. A route is defined by specifying an origin, destination, and mode. Examples of goal variables in the DODOTRANS system are maximum fare, average frequency of service, minimum travel time, and product of fares and trips. These illustrate the operations "maximum", "average", "minimum", and "product".

The user can define, and give names to, a number of goal fabrics. He can then evaluate the consequences of a particular action by computing the values of the goal variables in any goal fabric. Each goal variable can be computed over a number of ranges of evaluation. A range of evaluation consists of a set of one or more combinations of origins, destinations, and modes (for example, average travel time from Hartford to New York by air and by all modes; and from Hartford to all zones by air and by all modes).

The DODOTRANS user can also compare several actions by comparing the values of a particular goal variable for each of the actions. The actions are automatically ranked according to these values, and the minimum, maximum, and absolute and percentage differences are displayed.

To assist in evaluation, relevant consequences can be displayed graphically on plotter or scope by means of such commands as PLOT NETWORK, DISPLAY LINK VOLUMES, TRAVEL TIMES, SPEEDS. Several alternatives can be compared, to evaluate the differences between them, with such commands as

1. COMPARE TRIPS, for a summary of the differences between the two flow patterns;
2. COMPARE SURPLUSES, for comparison of user benefits as measured by consumer surplus; and
3. COMPARE ACCESSIBILITIES, for functional impacts.

Search

Two basic types of search capabilities are provided. A transportation system alternative can be generated explicitly by the user supplying the data or by calling a mathematical optimization formulation.

Generating an Alternative Explicitly—To generate an alternative explicitly, the following commands can be used.

1. Transportation options: (a) READ NETWORK, for general network characteristics; (b) LINKS, for network connectivity and link characteristics; (c) READ VOLUME DELAY SETS, for generalized supply functions; and (d) READ MODAL SERVICE DATA, for interzonal fares and frequencies and cost parameters for each mode.
2. Activity system options: (a) READ ACTIVITY, for populations, incomes, and holding capacities for each district; and (b) PARAMETERS, for demand model parameters.

In addition to specifying a completely new alternative, it is also possible to generate an alternative by using portions of another alternative previously stored in the computer:

3. STORE, to save a network, volume-delay set, modal service data, or activity pattern for an alternative on secondary storage as a permanent file for future reference.
4. To create a new alternative by modifying one previously stored on secondary storage: (a) MODIFY NETWORK, name of network is changed; ADD LINK, DELETE LINK, CHANGE LINK, specification of changes; (b) MODIFY MODAL DATA, name of data to be changed; MODE COST, MODE FREQUENCY, specification of changes; (c) READ ACTIVITY, name of data to be changed; DISTRICT, specification of changes.

Use of Mathematical Optimization—A communications system has been developed that allows the DODOTRANS user to set up an optimization formulation of his transportation search problem with a minimum of information describing the problem. After the formulation is set up, it may be executed using existing optimization packages, and the results are returned to DODOTRANS for output and, possibly, data modification.

Time-Staging of Network Improvements in the Face of Uncertainty—Uncertainty is an essential aspect of transportation planning. There will always be uncertainty as to demand, as to the characteristics of transportation technology, and as to the values, public and private, to be used in reaching a decision. This uncertainty must be recognized, and techniques for treating uncertainty explicitly must be an integral part of analysis of transportation systems (20).

One method for handling uncertainty uses the general techniques of decision theory (SDT) (21, 22). An early application of SDT to transportation problems was in the process of highway location (23). Later applications included pavement design (24) and traffic engineering problems (25).

The need to apply SDT to transportation planning per se was described in a recent survey report (5) where work then in progress was reported. More recently, Hutchinson (26) has outlined, in a simple example, the application of SDT to planning a rail demonstration project. The use of SDT in transportation planning is promising.

Significant advances in techniques are required to exploit the full potential of SDT. Since 1966, work has been under way at M.I.T. to develop such techniques. Johnson (27) has applied the Bayesian decision theory approach to the problem of determining how much information to collect in transportation planning. Jarmillo (28) explored alternative formulations of demand models suitable for Bayesian reference in the SDT framework. In work nearing completion, Pecknold (29) is developing practical computational techniques for applying SDT to realistic transportation problems.

While these efforts to develop specific techniques have been proceeding, it has been our long-term objective to integrate these results into our system of computer programs

for transportation analysis. To this end, preliminary capabilities have been incorporated into DODOTRANS for exploring the time-sharing of alternatives in the face of uncertainty.

Other Developments—Experiments are being conducted with a variety of other search techniques. As these are developed and tested, they will be incorporated into DODOTRANS. Of particular note are specific heuristic search techniques.

AN EXAMPLE OF THE USE OF DODOTRANS I

An example of the use of DODOTRANS I to perform transportation systems analysis is discussed in this section. This example is only meant to illustrate the DODOTRANS capabilities and commands, and therefore has little real-world significance. DODOTRANS has been used to analyze a real region, the Northeast Corridor, in a prototype analysis reported elsewhere (11), and is currently being used to analyze other prototype problems, including an urban transit corridor and an "airport access" problem.

Options

In order to demonstrate most of the major DODOTRANS commands, a hypothetical problem has been formulated. The analysis area, shown in Figure 3, consists of three districts in which intercity air and rail passenger travel is to be analyzed.

In order to keep the network simple, it is assumed that all intercity passengers in the three districts begin and end their trips in the district center, which is the location of the rail station. This assumption eliminates links representing travel to each air and rail station from scattered locations within the district. These could be added if desired.

A set of options representing an existing situation are illustrated in Figure 4 and Tables 1 and 2. The air mode has the lower fixed costs. The rail mode has the lower variable costs. Volume/time functions for air access roads and airports increase as volumes increase, reflecting possible congestion for air travelers until they become airborne. Rail line capacities are also limited, but rail station delays are constant, independent of volume.

Separate networks are developed, each reflecting the unique structure of access, terminal, and line-haul links for a particular mode. Governmental and operators'

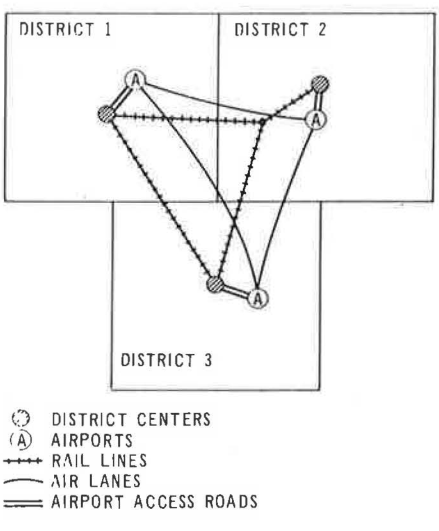


Figure 3. The analysis area.

TABLE 1
THE ACTIVITY SYSTEM: DISTRICT DATA

District	Population (in thousands)	Per Capita Income (dollars per year)	Holding Capacity (in thousands)
1	4,000	2,000	8,000
2	2,700	2,200	4,500
3	3,600	1,900	10,000

TABLE 2
THE ACTIVITY SYSTEM: DEMAND MODEL PARAMETERS

Constant	4.5×10^4
Exponents	
Origin population	0.5
Destination population	0.5
Origin income	0.5
Destination income	0.5
Fastest time	-2.09
Time ratio	-2.18
Lowest fare	-0.955
Fare ratio	-2.24
Most frequent	0.0
Frequency ratio	0.44

a. The technologies: Costs

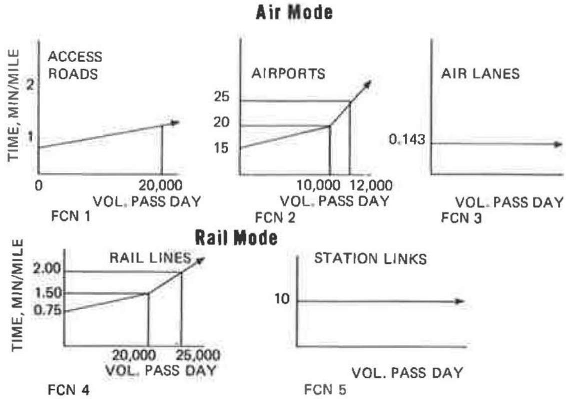
Air Mode

Fixed cost	$1.5 million per year
Variable cost	$0.05 per passenger-mile

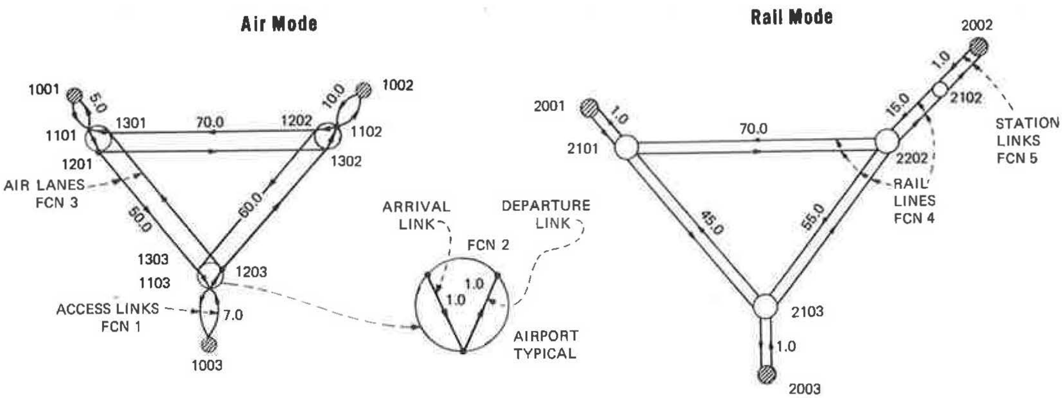
Rail Mode

Fixed cost	$5 million per year
Variable cost	$0.02 per passenger-mile

b. The technologies: Volume/Time Functions



c. The network



d. Operating policies

Air Mode

Subsidy = $500,000 per year; user tax = 5 percent of fare.

FREQUENCIES (departures per day)				FARES (dollars per trip)			
From District	To District 1	2	3	From District	To District 1	2	3
1	–	15	11	1	–	17	15
2	15	–	18	2	17	–	16
3	11	18	–	3	15	16	–

Rail Mode

Subsidy = $10,000 per year; user tax = 0

FREQUENCIES (departures per day)				FARES (dollars per trip)			
From District	To District 1	2	3	From District	To District 1	2	3
1	–	25	17	1	–	6.25	4.25
2	25	–	30	2	6.25	–	5.50
3	17	30	–	3	4.25	5.50	–

Figure 4. The options.

policies are specified for each mode in terms of subsidies, tax rates, and interdistrict fares and frequencies. The activity system is described as district data and demand model parameters (Tables 1 and 2).

Runs for the Existing Alternative

DODOTRANS commands describing the options shown in the figures were developed, and the prediction models were used to generate existing consequences and impacts.

The results of the computer runs for the existing data are given in the Appendix in runs 1 through 4, where both the input commands and the outputs are listed. These runs indicate that a total of 26,840 trips are made each day, 3,138 by air and 23,702 by rail. The average travel time for all trips is 72 minutes, and the average user cost is $10.11. Total yearly operator's profit is $12.0 million for the air mode and $27.1 million for the rail mode. Net annual government revenue is $0.4 million. These numbers are only some of the more aggregate measures determined by DODOTRANS. Many other useful numbers are provided in the output.

Proposed Changes

After establishing the "base case", proposed transportation changes can be evaluated. The following changes to the existing data were proposed for this example:

1. Construct a new direct rail link between districts 1 and 2, with a distance of 80 miles.
2. Improve airport design and procedures to reduce terminal delays to half of their original levels.
3. Double existing rail frequencies between districts 1 and 2 to 50 trains per day.
4. Reduce existing rail fares between districts 1 and 2 by $1.00 to $5.25 per trip.
5. Increase the average per capita income of district 2 residents by $100 to $2,300 per year.

All of these changes can be made simply by using DODOTRANS to modify the original data, which have been saved in named secondary storage files. These modifications create a new network and new district and modal data sets.

Runs for Proposed Alternative

The DODOTRANS commands that perform the modifications described in the preceding and then continue to predict new consequences and impacts are shown in runs 5 through 7. After the prediction and output phases are completed for the proposed alternatives, the DODOTRANS alternative comparison commands are used to compare the existing and proposed alternatives. Also, the change in accessibilities between the two alternatives is used to predict new populations and incomes.

Highlights of the alternative comparisons are that total trips have increased by 5,416, which is 20 percent higher than the base consequence. Air trips have increased 71 percent to 2,240, and rail trips have increased 13 percent to 3,176. The total change in consumer surplus per day, however, is -$7,209, thus indicating that in total the travelers are worse off after the proposed changes are made. Going back to less aggregated results, total consumer surpluses due to changes in travel times and waiting times are positive but are outweighed by a large decrease in consumer surplus resulting from changes in user fares.

The population predictions indicate that district 2 will grow slower than the other districts. The income predictions indicate that district 3 will have the smallest increase in income levels.

CONCLUSIONS

We want to stress the evolutionary nature of DODOTRANS. It is a "breadboard" on which we experiment with new models and approaches. As these are tested out, they are incorporated into the current operational version of the system.

DODOTRANS is an experimental system. We use it actively in our own teaching and research and are applying it to real problems. We are especially anxious to get critical evaluation of this system, suggestions for further development, and tests of its capabilities in real problems. Although the system has not been released for wide distribution, we would like to try to collaborate with anyone who would like to experiment with use of the system.

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Appendix

COMPUTER PRINTOUT DATA

```
READ NETWORK 'EXAMPLE' ZONES 6 VOL/DELAY SET 'EXAMPLE'

NETWORK EXAMPLE        INPUT NODES=        0      LINKS=        0

$   LINKS FRCM ZCNES FIRST

LINK 1 FROM 1001 TO 1101 DISTANCE 5 LANES 1 VOL/DELAY 1

LINK 2 1002 11C2 10 1 1, 1003 1103 7 1 1

LINK 3 2001 2101 1 1 5, 2002 2102 1 1 5, 2003 2103 1 1 5

$   AIR ACCESS LINKS

LINK 4 1101 1C01 5 1 1, 1102 1002 10  1 1, 1103 1003 7 1 1

$   NOW AIRPORT LINKS

LINK 5 1101 1201 1 1 2, 1301 1101 1 1 2

LINK 6 1102 1202 1 1 2, 1302 1102 1 1 2

LINK 7 1103 1203 1 1 2, 1303 1103 1 1 2

$   NOW AIR LANE LINKS

LINK 8 1201 13C2 70 1 3, 1201 1303 50 1 3

LINK 9 1202 1301 70  1 3, 1202 1303 60 1 3

LINK 9 1203 1301 50 1 3 , 1203 1302 60 1 3

$   RAIL LINKS - START WITH STATIONS

LINK 11 2101 2001 1 1 5, 2102 2002 1 1 5, 2103 2003 1 1 5
```

```
$   LINE HAUL RAIL LINKS
LINK 12 2101 2202 70 1 4, 2202 2101 70 1 4
LINK 13 2101 2103 45 1 4 , 2103 2101 45 1 4
LINK 14 2102 2202 15 1 4 , 2202 2102 15 1 4
LINK 16 2202 2103 55 1 4, 2103 2202 55 1 4
$   DUMMY LINKS
LINK 16 1001 2001 160 1 6, 2001 1001 160 1 6
EDIT NETWORK
NETWORK EXAMPLE  HAS BEEN READ

STORE NETWORK
NETWORK EXAMPLE  HAS BEEN STORED ON DISK.



$  RUN 1
DODOTRANS
READ VOL/DELAY SET 'EXAMPLE' FUNCTIONS 6 POINTS 3
  V/D 1 LOCAL 2 C 1 20000 2 40000 3  $  AIR ACCESS
  V/D 2 LOCAL 2 0 15 10000 20 12000 25  $  AIRPORTS
  V/D 3 ARTERIAL 2 0 .143 10000 .143 20000 .143  $  AIR LANES
  V/D 4 ARTERIAL 2 0 .75 20000 1.50 25000 2.0  $  RAIL LINES
  V/D 5 LOCAL 2 0 10 20000 10 40000 10  $  STATIONS
$  FOR DUMMY LINKS
  V/D 6 LOCAL 2 0 1 20000 1 40000 1
EDIT VOL/DELAY SET
          FUNCTICN    1 HAS NC ERRORS
          FUNCTICN    2 HAS NC ERRORS
          FUNCTICN    3 HAS NO ERRORS
          FUNCTICN    4 HAS NC ERRORS
          FUNCTICN    5 HAS NC ERRORS
          FUNCTICN    6 HAS NO ERRORS
VOLUME DELAY SET EXAMPLE  HAS BEEN READ

STORE VOL/DELAY SET
VOLUME DELAY SET EXAMPLE  HAS BEEN STORED ON DISK.

EJECT
```

```
READ MODAL SERVICE DATA SET '2/MODES', MODES 2 DISTRICTS 3

DATA FOR MODE 1, 'AIR'

FARE FROM ORIGIN 1 TO 2 17 TO 3 15

FARE FROM ORIGIN 2 TC 1 17 TO 3 16

FARE FROM ORIGIN 3 TO 1 15 TO 2 16

FREQUENCY FRCM ORIGIN 1 TO 2 15 TO 3 11

FREQUENCY FROM ORIGIN 2 TO 1 15 TO 3 18

FREQUENCY FRCM ORIGIN 3 TO 1 11 TO 2 18

DATA FOR MODE 2, 'RAIL'

FARE FRCM CRIGIN 1 TO 2 6.2 TO 3 4.2

FARE FROM ORIGIN 2 TO 1 6.2 TC 3 5.5

FARE FROM ORIGIN 3 TO 1 4.2 TO 2 5.5

FREQUENCY FRCM CRIGIN 1 TO 2 25 TO 3 17

FREQUENCY FROM ORIGIN 2 TO 1 25 TO 3 30

FREQUENCY FRCM ORIGIN 3 TO 1 17 TO 2 30

SYSTEM POLICIES MODE 'AIR' SUBSIDY 500000, FIXED COST 1500000,  -
     VARIABLE CCST RATE .05 TAX RATE .05

SYSTEM POLICIES MODE 'RAIL' SUBSIDY 10000, FIXED COST 5000000,  -
     VARIABLE CCST RATE .02 TAX RATE 0

EDIT MODAL CATA SET

MODAL FILE MEMBER 2/MODES  HAS BEEN STORED ON DISK

EJECT



READ ACTIVITY SYSTEM DATA SET 'DOT', DISTRICTS 3

DISTRICT 1 4CCC 2CCO 8000 'DIST1'

DISTRICT 2 2700 2200 4500 'DIST2'

DISTRICT 3 3600 19CO 10000 'DIST3'

EDIT ACTIVITY SYSTEM DATA SET


THE NUMBER CF DISTRICTS =     3
 ******  DISTRICT FILE MEMBER DOT       HAS BEEN STORED ON DISK.

PARAMETER 'NCRMAL'

MODAL SPLIT PARAMETERS 'B-Q' 4.5E4 .5 .5 .5 .5 -2.09 -2.18 -.955 -2.24 0 .44

DISTRICT GROWTH PARAMETERS 'EXAMPLE' ACCESS 1 POPULATION GROWTH .02  -
     REGIONAL PRCDUCT GROWTH .035
```

```
INCREMENT 25 PERCENT
STOP DEFINITION OF PARAMETERS
 ******  END OF CURRENT DEFINITION OF PARAMETER NORMAL

 ******  MODAL SPLIT DATA B-Q        HAS BEEN STORED ON DISK.

 ******  DISTRICT GROWTH DATA EXAMPLE  HAS BEEN STORED ON DISK.

EJECT




$   RUN 2
$   SET UP THE BASE ACTION
ACTION 'BASE'
STRATEGY 'TEST' STAGE 1 YEAR 1965
DESCRIPTORS OF ACTION FOLLOW
NETWORK 'EXAMPLE'
DISTRICT DATA 'DOT'
MODE DATA '2/MODES'
VOL/DELAY DATA 'EXAMPLE'
STOP DEFINITION OF ACTION
 ******  END OF CURRENT DEFINITION OF ACTION BASE

$   PREDICT BASE CONSEQUENCES
PREDICT CONSEQUENCES 'BASE', ACTION 'BASE', PARAMETERS 'NORMAL'
STOP PREDICTION OF CONSEQUENCES
 ******  END OF DEFINITION OF CONSEQUENCE BASE


    THE NETWORK IS COMPLETELY ASSIGNED AFTER   218 ITERATIONS
          TIME USED SINCE START OF RUN IS    0.08 MINUTES

DATA HAS BEEN STORED ON DISK IN DATA FILE BASE
```

```
                         FINAL OUTPUT

          TRAVEL TIME OUTPUT BASE      FUR NETWORK EXAMPLE

                        OUTPUT ON DISK

VALUATION FILE MEMBER BASE     HAS BEEN STORED ON DISK.

 ******  BASIC DECISION MODULE      1

 ******       ACTICNS  BASE
 ******       PARMETER NORMAL
 ******       CCNSGNCE BASE




$    RUN 3

$    OUTPUTS FRCM CONSEQUENCE BASE

LOAD FLOW DATA 'BASE'

$    TRIP VOLLMES

REQUEST CONSEQUENCES, INTERZONAL TRIPS FOR ALL ZONES
                              TOTAL INTERZONAL TRIPS ASSIGNED

                               FLCW PATTERN NAME IS BASE

                               DISTRICT        DISTRICT
                                NUMBER           NAME


                                  1            DIST1
                                  2            DIST2
                                  3            DIST3



                    THIS IS THE MATRIX FOR     3 DISTRICTS AND    2 MODES
                        WHICH GIVES THE ASSIGNED INTERZONAL VOLUMES
                       FOR ALL DISTRICT PAIRS, IN PASSENGERS PER DAY.

                                  AIR      MODE TRIPS


  TO DISTRICT    1        2        3
FROM DISTRICT
      1          0      540      512
      2        539        0      518
      3        511      518        0
```

RAIL MODE TRIPS

TO DISTRICT / FROM DISTRICT	1	2	3
1	0	2227	6378
2	2227	0	3246
3	6378	3246	0

$ TRAVEL TIMES

REQUEST CONSECUENCES, TRAVEL TIMES FOR ALL ZONES

FINAL OUTPUT

TRAVEL TIME OUTPUT FOR NETWORK EXAMPLE

THIS IS THE TABLE TO CONVERT MACHINE NODE NUMBERS TO USER NODE NUMBERS

MACHINE NUMBERS	1	2	3	4	5	6
0 USER NUMBERS	1001	1002	1003	2001	2002	2003

THE FOLLOWING MATRIX USES MACHINE NODE NUMBERS

THIS IS THE MATRIX FOR 6 ZONES WHICH GIVES THE TRAVEL TIMES BETWEEN ALL ZONE PAIRS IN MINUTES.

TO ZONE / FROM NODE	1	2	3	4	5	6
1	0.0	56.84	50.84	160.00	252.68	224.52
2	56.84	0.0	57.48	216.84	309.52	281.36
3	50.84	57.48	0.0	210.84	303.52	275.36
4	160.00	216.84	210.84	0.0	92.68	64.52
5	252.68	309.52	303.52	92.68	0.0	82.28
6	224.52	281.36	275.36	64.52	82.28	0.0

$ ACCESSIBILITIES

REQUEST CONSEQUENCES, ACCESSIBILITIES

ACCESSIBILITIES FOR FLOW PATTERN BASE

NETWORK EXAMPLE

ORIGIN DISTRICT	MODE AIR	RAIL	ALL MODES
DIST1	1.17617E 03	9.62068E 03	1.07969E 04
DIST2	1.37145E 03	7.10120E 03	8.47266E 03
DIST3	1.24419E 03	1.16366E 04	1.28808E 04
ALL ORIGINS	1.25114E 03	9.66484E 03	1.09160E 04

$ LINK FLOW CATA

REQUEST CONSEQUENCES, LINK VOLUMES,SPEEDS,AND TIMES FOR ALL LINKS

LINK TABLE
THIS TABLE IS FOR ALL LINKS IN NETWORK EXAMPLE

LINK FRCM	TO	TRAFFIC VOLUME (PASSENGERS PER DAY)	SPEED (MILES PER HOUR)	TRAVEL TIME (MINUTES)
1001	1101	1052	56.8	5.28
1001	2001	0	60.0	160.CO
1002	1102	1057	57.0	10.52
1003	1103	1029	57.1	7.36
2001	2101	8605	6.0	10.00
2001	1001	0	60.0	160.00
2002	2102	5473	6.0	10.CC
2003	2103	9624	6.0	10.00
11C1	1001	1050	56.8	5.28
11C1	1201	1052	3.9	15.52
1102	1002	1058	57.0	10.52
11C2	1202	1057	3.9	15.52
1103	1003	1030	57.1	7.36
1103	1203	1029	3.9	15.52
1301	1101	1050	3.9	15.52
1302	1102	1058	3.9	15.52
13C3	1103	1030	3.9	15.52
1201	1302	540	420.0	10.00
1201	1303	512	419.0	7.16
1202	1301	539	420.0	10.00
1202	1303	518	420.6	8.56
1203	1301	511	419.0	7.16
1203	1302	518	420.6	8.56
2101	2001	8605	6.0	10.00
2101	2103	6378	60.6	44.52
21C1	2202	2227	72.0	58.36
2102	2002	5473	6.0	10.00
2102	2202	5473	62.8	14.32
2103	2003	9624	6.0	10.CO
2103	2202	3246	68.8	47.96
2103	2101	6378	60.6	44.52
2202	2101	2227	72.0	58.36
2202	2102	5473	62.8	14.32
2202	2103	3246	68.8	47.96

COST SUMMARIES FOR FLOW PATTERN BASE

NETWORK EXAMPLE

DAILY USER DATA BY MODE AND ORIGIN

MODE	ORIGIN DISTRICT	TOTAL TRIPS (PASS/DAY)	USER FARES TOTAL ($)	USER FARES AVERAGE ($/TRIP)	USER TRAVEL TIME TOTAL (HOURS)	USER TRAVEL TIME AVERAGE (MIN/TRIP)
AIR	DIST1	1052	1.68600E 04	16.03	9.45395E 02	54.
AIR	DIST2	1057	1.74510E 04	16.51	1.00686E 03	57.
AIR	DIST3	1029	1.59530E 04	15.50	9.29231E 02	54.

RAIL	DIST1	8605	4.05950E 04	4.72	1.02984E 04	72.
RAIL	DIST2	5473	3.16604E 04	5.78	7.89132E 03	87.
RAIL	DIST3	9624	4.46406E 04	4.64	1.13098E 04	71.

USER WAIT TIME TOTAL (HOURS)	USER WAIT TIME AVERAGE (MIN/TRIP)	WEIGHTED COSTS TOTAL ($)	WEIGHTED COSTS AVERAGE ($/TRIP)
1.18865E 03	67.79	2.11281E 04	20.08
9.31839E 02	52.90	2.13284E 04	20.18
1.08334E 03	63.17	1.99781E 04	19.42
6.68528E 03	46.61	7.45624E 04	8.67
2.84083E 03	31.14	5.31247E 04	9.71
6.96061E 03	43.40	8.11814E 04	8.44

DAILY USER DATA BY MODE

MODE	TOTAL TRIPS (PASS/DAY)	USER FARES TOTAL ($)	USER FARES AVERAGE ($/TRIP)	USER TRAVEL TIME TOTAL (HOURS)	USER TRAVEL TIME AVERAGE (MIN/TRIP)
AIR	3138	5.02640E 04	16.02	2.88148E 03	55.
RAIL	23702	1.16896E 05	4.93	2.94996E 04	75.
TOTALS	26840	1.67160E 05	6.23	3.23810E 04	72.

USER WAIT TIME TOTAL (HOURS)	USER WAIT TIME AVERAGE (MIN/TRIP)	WEIGHTED COSTS TOTAL ($)	WEIGHTED COSTS AVERAGE ($/TRIP)
3.20384E 03	61.26	6.24346E 04	19.90
1.64867E 04	41.74	2.08868E 05	8.81
1.96906E 04	44.02	2.71303E 05	10.11

YEARLY COSTS AND REVENUES BY MODE

MODE	TOTAL TRIPS	USER FARES	TOTAL USER COSTS	OPERATOR'S PROFIT
AIR	1145370	1.83464E 07	2.27886E 07	1.20273E 07
RAIL	8651230	4.26670E 07	7.62370E 07	2.70595E 07
TOTALS	9796600	6.10134E 07	9.90256E 07	3.90868E 07

GOVERNMENT REVENUE	OPERATOR'S PROFIT PER PASSENGER	GOVT. REVENUE PER PASSENGER
4.17318E 05	10.50	0.36
-1.00000E 04	3.13	-0.00
4.07318E 05	3.99	0.04

```
WRITE FVALUATION RESULTS FOR GOAL FABRIC 'EXAMPLE', VARIABLES ALL
     UTILITIES ALL CONSEQUENCES 'BASE'
```

GOAL VARIABLE NAME	UTILITY FUNCTION NAME	CONSEQUENCE FILE NAME	VALUE	
AVEFARE	2-ONES	BASE	6.23	
AVETIME	2-ONES	BASE	72.39	
TOTTRIP	ONE	BASE	3138.00	MODE AIR
TOTTRIP	ONE	BASE	23702.00	MODE RAIL
TOTTRIP	ONE	BASE	26840.00	MODE ALL

```
$   RUN 4

$    DEFINITION AND EVALUATION OF A GOAL FABRIC

GOAL FABRIC 'EXAMPLE'

'AVEFARE' = AVERAGE INTERDISTRICT FARES, TRIPS

'AVETIME' = AVERAGE INTERDISTRICT TIMES, TRIPS

'TOTTRIP' = SUM INTERDISTRICT

     TRIPS

     END
```

```
STOP DEFINITION OF GOAL FABRIC

 ******  END OF CURRENT DEFINITION OF GOAL FABRIC EXAMPLE

UTILITY FUNCTION 'ONE', 1 VALUE, 1

 ******  UTILITY VECTOR ONE      HAS BEEN DEFINED WITH  1 VALUES

UTILITY FUNCTION '2-ONES', 2 VALUES, 1 1

 ******  UTILITY VECTOR 2-ONES   HAS BEEN DEFINED WITH  2 VALUES

$

EVALUATE GOAL FABRIC 'EXAMPLE', CONSEQUENCES 'BASE'

UTILITY 'ONE'

'TOTTRIP' FROM ALL TO ALL BY EACH

 ******  GOAL VARIABLE TOTTRIP  HAS BEEN EVALUATED WITH UTILITY ONE

'TOTTRIP' FROM ALL TO ALL BY ALL

 ******  GOAL VARIABLE TOTTRIP  HAS BEEN EVALUATED WITH UTILITY ONE

UTILITY '2-ONES'

'AVEFARE' FROM ALL TO ALL BY ALL

 ******  GOAL VARIABLE AVEFARE  HAS BEEN EVALUATED WITH UTILITY 2-ONES

'AVETIME' FROM ALL TO ALL BY ALL

 ******  GOAL VARIABLE AVETIME  HAS BEEN EVALUATED WITH UTILITY 2-ONES

STOP EVALUATION OF GOAL FABRIC



$   RUN 5

MODIFY NETWORK 'EXAMPLE' FORMING 'FUTURE'

$  ADD NEW DIRECT RAIL LINK BETWEEN DISTRICTS 1 AND 2, DISTANCE 80

ADD LINKS 2101 2102 80 1 4, 2102 2101 80 1 4

$  CHANGE AIRPORT DESIGN AND PROCEDURES, REDUCING DELAYS IN HALF

CHANGE LINKS 1001 1101 .5 1 1, 1101 1001 .5 1 1, 1002 1102 .5 1 1  -
     1102 1002 .5 1 1 , 1003 1103 .5 1 1,  1103 1003 .5 1 1

EDIT NETWORK

STORE NETWORK

NETWORK FUTURE   HAS BEEN STORED ON DISK.
```

```
MODIFY MODAL SERVICE DATA '2/MODES'

$   DOUBLE RAIL FREQUENCIES BETWEEN 1 AND 2, TO 50

MODE 2 FREQUENCY 1 2 50

MODE 2 FREQUENCY 2 1 50

$  REDUCE RAIL FARES BY 1.00 BETWEEN 1 AND 2, TO 5.25

MODE 2 FARE 1 2 5.25

MODE 2 FARE 2 1 5.25

EDIT MODAL SERVICE DATA

STORE MODAL DATA 'CHANGED'

MODAL FILE MEMBER CHANGED  HAS BEEN STORED ON DISK

$  INCREASE DISTRICT 2 INCOME TO $2300.

MODIFY ACTIVITY SYSTEM DATA 'DOT'

DISTRICT 2 POPULATION 2700 INCOME 2300 HOLD/CAP 4500 NAME 'DIST2'

EDIT ACTIVITY SYSTEM DATA

STORE ACTIVITY SYSTEM DATA 'DOT-2'
 ******  DISTRICT FILE MEMBER DOT-2    HAS BEEN STORED ON DISK.

EJECT




$  RUN 6

$  PREDICT CONSEQUENCES FOR PROPOSED CHANGES

ACTION 'PROPOSED'

STRATEGY 'TEST' STAGE 2 YEAR 1975

INCLUDES 'BASE'

DESCRIPTORS OF ACTION FOLLOW

NETWORK 'FUTURE'

DISTRICT DATA 'DOT-2'

MODE DATA 'CHANGED'

VOL/DELAY DATA 'EXAMPLE'

STOP DEFINITION OF ACTION

 ******  END OF CURRENT DEFINITION OF ACTION PROPOSED
```

PREDICT CONSEQUENCES 'PROPOSED', ACTION 'PROPOSED',PARAMETERS 'NORMAL'

DISTRICT DATA 'DCT-3' YEAR 1980

STOP PREDICTION OF CONSEQUENCES

****** END OF DEFINITION OF CONSEQUENCE PROPOSED

THE NETWORK IS COMPLETELY ASSIGNED AFTER 230 ITERATIONS

TIME USED SINCE START OF RUN IS 0.09 MINUTES

DATA HAS BEEN STORED ON DISK IN DATA FILE PROPOSED

FINAL OUTPUT

TRAVEL TIME OUTPUT PROPOSED FOR NETWORK FUTURE

OUTPUT ON DISK

VALUATION FILE MEMBER PROPOSED HAS BEEN STORED ON DISK.

ACTIVITY SYSTEM PREDICTIONS

FOR VALUATION DATA PROPOSED

BASED ON BASE

ORIGIN DISTRICT	BASE YEAR POPULATION IN MILLIONS	PREDICTED POPULATION IN MILLIONS	PERCENT INCREASE
DIST1	4.000	4.411	10.28
DIST2	2.700	2.885	6.85
DIST3	3.600	4.034	12.05

BASE YEAR PER CAPITA INCOME	PREDICTED PER CAPITA INCOME	PERCENT INCREASE
2000.	2170.	8.51
2300.	2575.	11.97
1900.	1916.	0.87

REGIONAL TOTALS

	BASE YEAR	PREDICTION	PERCENT INCREASE
POPULATION IN MILLIONS	10.300	11.330	10.00
NET REGIONAL PRODUCT (BILLIONS OF DOLLARS)	21.050	24.734	17.50

```
$ RUN 7

$ COMPARE BASE AND PROPOSED

COMPARE TRIPS AND SURPLUSES, VALUATION 'PROPOSED' AND VALUATION 'BASE' -
    TIME VALUE 2.35 WAIT FACTOR .40
```

COMPARISON OF VALUATION FILES PROPOSED AND BASE

FLOW PATTERNS PROPOSED AND BASE

VALUES SHOWN ARE (FILE PROPOSED) - (FILE BASE)

CHANGE IN TRIPS

ORIGIN DISTRICT	AIR	MODE RAIL	ALL MODES
DIST1	594	1555	2149
DIST2	790	1689	2479
DIST3	856	-68	788
ALL ORIGINS	2240	3176	5416

CHANGE IN CONSUMER TRAVEL TIME SURPLUS
(PASSENGER-HOURS PER DAY)

ORIGIN DISTRICT	AIR	MODE RAIL	ALL MODES
DIST1	2.80417E 02	-2.91191E 02	1.21923E 02
DIST2	3.63478E 02	1.08797E 02	6.69151E 02
DIST3	3.22553E 02	3.52830E 01	6.41798E 02
ALL ORIGINS	9.66448E 02	-1.47111E 02	1.43287E 03

CHANGE IN CONSUMER TRAVEL COST SURPLUS
(DOLLARS PER DAY)

ORIGIN DISTRICT	AIR	MODE RAIL	ALL MODES
DIST1	6.70424E 01	1.09129E 03	-2.55107E 03
DIST2	1.09161E 02	2.65572E 03	-8.79294E 02
DIST3	-7.34978E 01	-7.29738E 01	-8.34360E 03
ALL ORIGINS	1.02706E 02	3.67404E 03	-1.17740E 04

CHANGE IN CONSUMER WAITING TIME SURPLUS
(PASSENGER-HOURS PER DAY)

ORIGIN DISTRICT	AIR	MODE RAIL	ALL MODES
DIST1	-1.95055E 01	2.24418E 03	1.99488E 03
DIST2	2.91071E 01	1.50734E 03	1.30310E 03
DIST3	6.23613E 01	3.43440E 01	-3.02662E 02
ALL ORIGINS	7.19629E 01	3.78587E 03	2.99532E 03

CHANGE IN CONSUMER WEIGHTED FRICTION SURPLUS
(WEIGHTED FRICTION = TRAVEL COST SURPLUS
+ 2.35 * TRAVEL TIME SURPLUS
+ 0.94 * WAITING TIME SURPLUS)

ORIGIN DISTRICT	MODE AIR	RAIL	ALL MODES
DIST1	7.18219E 02	1.30466E 03	-1.46660E 03
DIST2	9.74977E 02	3.51433E 03	1.21445E 03
DIST3	7.C9446E 02	2.36788E 01	-6.95644E 03
ALL ORIGINS	2.40264E 03	4.84267E 03	-7.20858E 03

CCMPARE GOAL FABRIC 'EXAMPLE'

BASE CCNSECUENCE 'PASE'

CCNSEQUENCE SFT 'BCTH'

BASE UTILITY 'ONE'

GOAL VARIABLE		CCNSEQUENCE	VALUE	RANKING	DIFFERENCE - BASE ABSOLUTE	PERCENT
*** TOTTRIP ******						
ORIGIN ALL						
DEST ALL						
MODE AIR		BASE	3138.00	2	0.0	0.0
		PROPOSED	5378.00	1	2240.CC	71.38
ORIGIN ALL						
DEST ALL						
MODE RAIL		BASE	23702.CO	2	0.0	0.0
		PROPOSED	26878.00	1	3176.CC	13.40
*** TOTTRIP ******						
ORIGIN ALL						
DEST ALL						
MODE ALL		BASE	26840.00	2	0.0	0.0
		PROPOSED	32256.CC	1	5416.CC	20.18
*** AVEFARE ******						
ORIGIN ALL						
DEST ALL						
MODE ALL		BASE	6.23	2	0.0	0.0
		PROPOSED	6.68	1	0.45	7.29
*** AVETIME ******						

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ORIGIN ALL
DEST   ALL
MODE   ALL     BASE                    72.39       1                 0.C     C.0

               PROPOSED                69.93       2               -2.46   -3.40

   STCP COMPARISON CF GCAL VARIABLES

    ******  FND CF GCAL FARRIC CCMPARISON

   EJFCT
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