CANPASS: A Strategic Planning Capability for Intercity Passenger Transportation

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INTRODUCTION

The specification for the CANPASS System derives from extensive practical experience in multimodal transportation planning and analysis. The system was designed as an integrative operational tool to support the activities of the various policy and administrative groups within Transport Canada. In any large highly structured organization dealing with a wide range of problems, coordination can present a problem. The need for a capability such as the CANPASS System was foreseen in a report issued by the Conference Board in 1972: [1]

„The policy-making task is of a magnitude and variety that precludes the possibility that decisionmaking can be centralized in any one spot... Independent actions may result in chaos unless they operate within some intellectual framework, some commonly shared body of knowledge, prediction and argument that can impart a measure of coherence and direction to the sum of independent decisions." [2]

Since transportation is increasingly being evalutated in holistic terms, effective management requires both information and the means of applying that information to specific types of problems in a rapid effective manner. To quote again from the Conference Board Report: [3]

"...there are relatively few integrated basic research projects involving systems formulation, software, hardware and mathematical models. But, these total applications of information technology are necessary for effective management of today's large scale economic and social problems such as health care, environmental control, public transportation, land use and resource allocation."

The CANPASS System is an integrated system of database, software and mathematical models oriented to multimodal intercity passenger transportation (hence the designation). The purpose of the system is to provide a common source of data and analysis capabilities for use by the policy/evaluation groups and model administrations in Transport Canada. It is hoped, in line with the recommendations in the Conference Board Report, that the system will facilitate information transfer within Transport Canada and result in a common definition of problems and in the joint resolution of these problems.

The paper describes the database, software and demand model elements of the CANPASS System. The description of each component is necessarily brief, but it is hoped to convey an outline of the capability of the system and its relevance to multimodal planning by a central government agency. The next section provides an overview of the CANPASS System.

AN OVERVIEW

To give an initial overview of the system, the various major elements and their interrelationships are shown in Figure 1. The database describes in detail the infrastructure and supply of intercity passenger transport services between 700 communities across Canada. Modal fares and modal origin-destination demand are also included. The software consists of three linked packages each designed to address a particular type of problem.

The CANPASS-3 software is designed to provide reports from the detailed database, to provide extensive analyses of itineraries through the modal systems and give detailed reports on accessibility and interaction potential.

For comparing the implications of policy options, one does not need the detail available at the CANPASS-3 level. It would be very onerous, time consuming and expensive to manipulate real-time schedules and detailed fare data when examining a wide range of options. To simplify such analyses, the CANPASS-2 software is designed to analyse modal systems described in terms of frequency of service and fare functions.

To utilize the wealth of data available in the database, a module entitled NETAGG has been designed to transform and aggregate data from the CANPASS-3 to the CANPASS-2 level. In a few hours, one can establish the "background" activity system and modal supply definitions upon which one can easily impose specific policy options, be they demographic, system or fare changes. The CANPASS-2 software is then used to explore the consequences of these policy options in terms of modal demand shifts, service patronage, revenues, accessibility, etc.

For such policy analyses, one needs demand models. This capability is provided by a module entitled DEMEX which is, in fact, a library of calibrated demand models. The user specifies the model most appropriate for his purpose or he can sequentially use different demand models to obtain a range of possible consequences.

The third software package is conceptually different to the previous analysis approaches. Whereas CANPASS-2 determines the probable demand response to offered services (i.e. to a predefined set of modal services), CANPASS-1 software is oriented to multimodal equilibrium analyses of transport supply and demand. Here, the calibrated demand models are used to represent the demand functions and explit schedules of transport supply for equivalent levels of demand are specified. The software defines the modal network configurations and levels of service when each modes' supply and demand are in equilibrium as a result of intermodal competition.

The CANPASS System thus provides both data and

CANPASS-3 DATABASE				
COMMUNITIES AND SOCIO-ECONOMIC DATA				
	AIR	BUS	RAIL	HIGHWAY
facilities	,,	,,	,,	Highway
access links	,,	,,	,,	Link
carriers	,,	,,	,,	Attributes
services	,,	,,		
schedules	,,	,,	,,	,,
O-D flows	,,	,,	,,	
fares	,,	,,	,,	

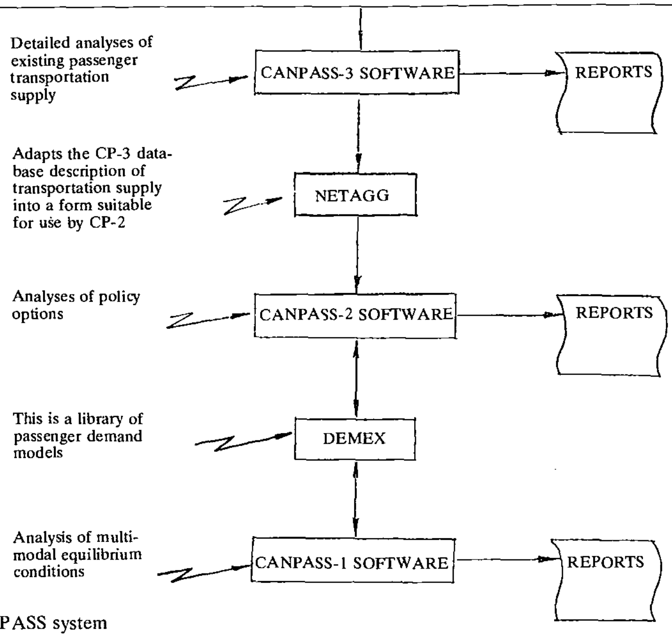

Figure 1 - The CANPASS system

the means to apply the data to a wide range of problems. As such, the system has the potential to serve a basic integrative role in policy planning and administration, and constitutes the basis of an effective decision support system.

THE CANPASS DATABASE

The database is designed to serve four functions:

1. to support national and regional multimodal passenger transportation studies of existing modal systems and the consequences of policy options;
2. to serve a data retrieval function;
3. to serve as an historical record, i.e. an archival function. This presupposes that the database is maintained on an annual basis;
4. to provide a framework for integrating data collected in other areas of Transport Canada.

In establishing a transportation database, the first problem is to define the extent of the activity system. Since the basic objective of passenger transportation is to provide for interaction between people, it was decided to orient the database to intercommunity service. This implies that a basic set of communities must be defined as a framework for the database. To do this, a National Urban Classification [4] was undertaken in conjunction with the Department of Regional Economic Expansion. This study selected 701 communities across Canada and ranked them in a seven tier hierarchy or class system corresponding to their importance within their regional context. The communities encompass 77.6% of the Canadian population.

The CANPASS database addresses the intercity air, bus, rail, ferry and highway modes and consists of ten principal files. A very straightforward approach was adopted to facilitate the incorporation of additional data and to make the database as flexible as possible. An outline of each of these files is given below:

1. Community File:
defines the name, class, geocode and a unique structured number for each of the 701 communities. Socio-economic data required by the demand models is also provided (e.g. population, linguistic characteristics, etc.) both for historic censal years and future "scenarios". Additional communities may be included as required.

2. Enumeration Area File:
each community is defined in terms of its constituent enumeration areas with their geocodes. This allows access to the Census of Canada data files to obtain more detailed socio-economic community data as required.

3. Facility File:
defines the name, quality, geocode and a unique structured number for all air, bus, rail and ferry access/egress points (i.e. airports, railway stations etc.) serving the above communities. Attributes of the facilities are also provided, such as minimum inter-portal transfer times, entry time, etc.

4. Access Link File:
provides the distance, time and cost from the commu-

nity population centroid to each modal facility plus inter-facility data where a community has more than one facility.

5. Carrier File:
gives the name and designation of all modal operators offering passenger service between any of the communities. Additional carrier data (e.g. employment, revenues, etc.) may be added.

6. Scheduled Service File:
defines the route structure of all modal services and the arrival and departure times at all facilities on the route: a unique identifying number is assigned to each service.

7. Service File:
provides for each of the above scheduled services such data as days of operation, equipment used, amenities provided. Additional service data such as energy usage, revenue and operating cost data may be added.

8. Fare File:
details the "basic" fare between each pair of facilities for each mode of transport.

9. Highway Link File:
defines characteristics (e.g. number of lanes, speed limit, traffic volumes) of each link of the highway network connecting the 701 communities. Additional data pertaining to physical characteristics and traffic flows may be added.

10. Origin-Destination Demand:
provides modal origin to destination demand for each community pair.

A more complete description of the database files is given in Appendix A.

CANPASS SOFTWARE

The software which consists of some 52 major programming elements has been designed from a user point of view and makes extensive use of the Wylbur preprocessor system to simplify use of the system. The user is guided by a sequence of questions as to his requirements and can call for "help" at any stage of the process. When the user requirements are specified, the Wylbur system assembles the necessary software and data elements and submits the "job" for batch processing. The system can thus be considered interactive to a certain degree, but the use of "foreground" interactive capability such as TSO was not considered necessary for this type of application. Use is made of variety of languages (e.g. Cobol, Fortran, PLI) as judged appropriate for the task at hand.

Although the system is designed primarily to produce formal reports, the need to provide for other analyses has been recognised. The flow of processed data within the system can be tapped and reformatted for use with the Statistical Package for the Social Sciences (SPSS). Additional software capabilities have been developed to supplement the CANPASS system. These include DEMON, a statistical capability for calibrating demand models and a model for estimating O-D from link flow data. [5] These elements are however not described here.

CANPASS-3 SOFTWARE

The CANPASS-3 package is designed to act on and analyse the air, bus, rail and ferry data at the detailed level given in the CANPASS database. A parallel software package carries out similar functions for the highway mode.

The package provides capabilities in four areas as follows:

1. Manipulation of the database

a. Subfile: this module allows the user to establish a subset of the master national database oriented to a particular study area, i.e. a problem area database.

b. Update: this capability allows the user to change an element in his problem area database, e.g. change services, route structure, schedules, insert or delete facilities, etc. The user can thus fine tune existing systems to improve coordination, integration, level of service, accessibility, etc.

2. Reports from the database

a. The user can request reports from any of the files in the database, impose "screens" to eliminate unwanted data, and asked for data associations (e.g. detail modal services at all facilities accessible by residents of a town).

3. Intercity Itineraries

a. Detailed Itineraries: provides times, distance, fare and speed data for all itineraries between specified city pairs on a specified day. The user can impose constraints such as "within X% or Y hours of fastest time".

b. Summary Itineraries: details only the maximum, minimum and average itinerary attributes from the above.

c. Return Trip Analysis: details the possibility of a day (or "n" day) return trip starting out and arriving back in user-specified periods of the day for specified city pairs.

4. Accessibility Analyses

a. Accessibility detail report: shows "best" times, distance, speed, time and fare from a specified community to all other communities arranged in order of class.

b. Summary Accessibility report: provides distributions of time, cost, etc. in user-specifiable intervals from subject community to classes of community, and population.

The above capability directly addresses problems of modal performance, efficiency, coordination, integration, level of service, accessibility, equity, adequacy and, of course, the control, direction, subsidy and evaluation functions of a central government agency. It provides the information and analyses to facilitate communication, problem definition and problem resolution within the central agency and between the central government and the provincial, regional or local governments.

CANPASS-2 SOFTWARE

The CANPASS-2 software is oriented towards policy exploration – the "what if" type of analysis. As discussed earlier, a more "abstract" level of system representation is appropriate for comparative analysis of policy options. The conceptual organisation of a CANPASS-2 application is shown in Figure 2.

The existing modal supply situation is first defined using data already available in the database. A module entitled NETAGG is used to establish this "background" definition. The module enables the user to define a suitable "activity system" from the 701 communities by selecting and aggregating communities as required. The existing modal systems serving the new "activity system" are extracted and redefined in terms of frequency of service by NETAGG. In a few hours the analyst can thus "set up" to do any type of policy analysis.

Phase A of CANPASS-2 analyses each modal system sequentially to establish modal supply attribute files (i.e.

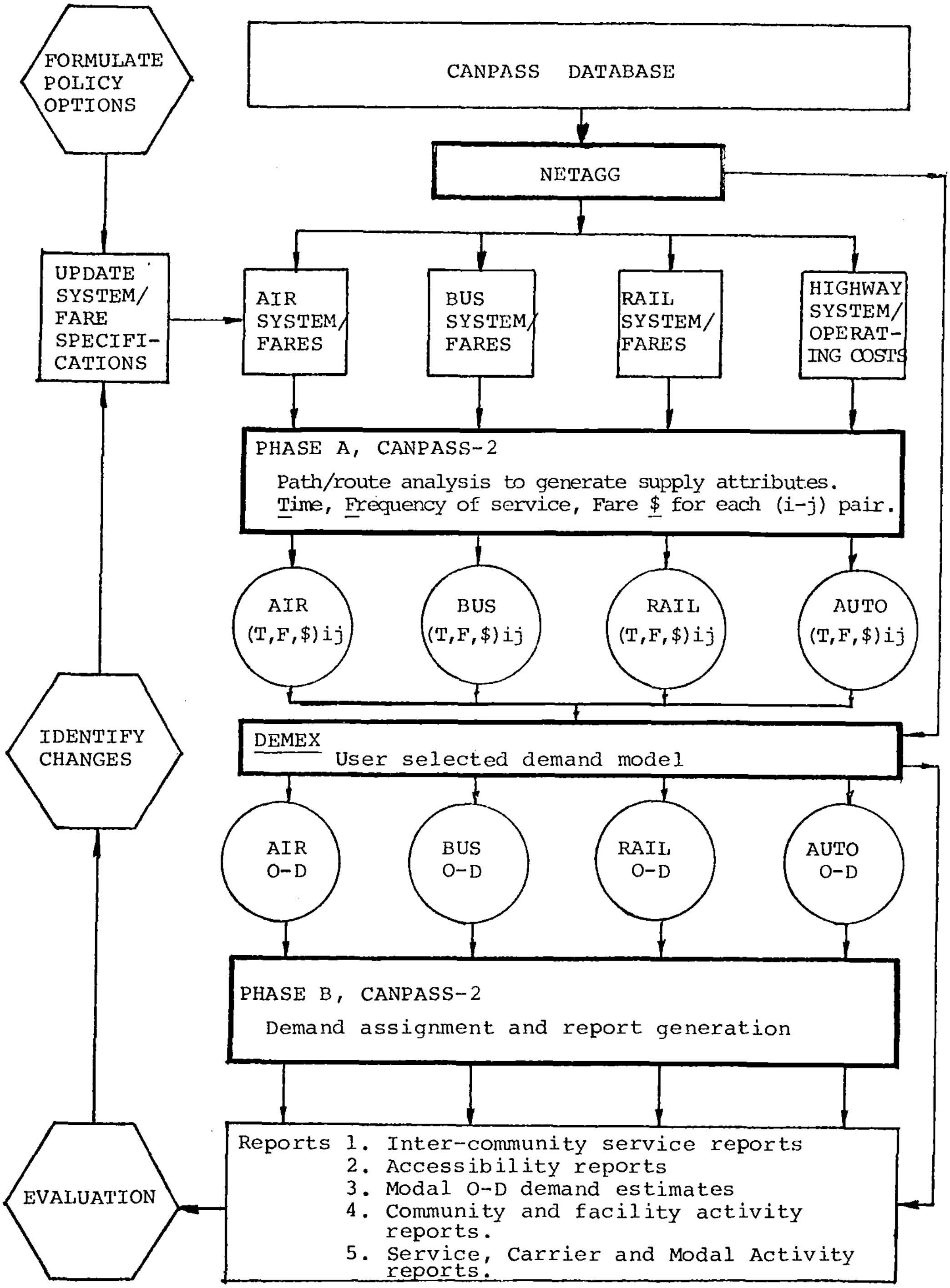

Figure 2 - Flow Chart for CANPASS-2 application

travel time, service frequency, travel cost between each origin and destination). These provide the necessary inputs (together with appropriate community socio-economic data) for a calibrated demand model to estimate both total and modal passenger travel demand. The modal O-D estimates are now available for use by Phase B of CANPASS-2. Modal O-D demand is assigned to routes and services and an array of reports are generated.

The analyst can now evaluate the reports, identify possible changes to the modal systems or fare structures and impose these on the previous system/fare descriptions using the update capability.

The reports generated by CANPASS-2 include:

1. Inter-community service reports:
the time, distance, fare, speed etc. by six types of route (e.g. one segment, multi segment/non stop, "n" stop, etc.). The user can specify which level of detail he requires and can obtain any one of five reports.

2. Accessibility reports:
similar to the CANPASS-3 accessibility reports.

3. Modal Origin-Destination reports:
matrices of estimated modal O-D demand.

4. Excessive Transfer reports:
identifies instances where direct service would be possible.

5. Community Activity reports:
originating and destined modal demand by community in terms of the facility utilised.

6. Facility Activity reports:
originating, destined and through demand, services, capacity provided and transferring passengers and average transfer times.

7. Service Activity reports:
utilisation, load factors, capacity, revenues, costs profit/loss, energy consumption etc. for each modal service.

8. Carrier Activity reports:
as above aggregated for each carrier.

9. Modal System report:
as above aggregated for each mode.

This extensive range of reports provides most of the data required to evaluate alternative policy options in comparative terms. Detailed submodels to deal with such items as noise incidence at airports etc. could, of course, be added but it is essential to preserve a balance between level of detail and the confidence one can assign to such detail in this type of modelling. Certainly the CANPASS-2 software provides the type of analysis capability required by central agencies to comparatively evaluate various policy options. Once one or two are selected, these can be examined in detail – perhaps at the CANPASS-3 level.

PASSENGER DEMAND MODELS

A library of fully specified and calibrated aggregate demand models is provided by the DEMEX module of the CANPASS System. More than one model is included for two reasons:

a. different models with different functional forms produce different elasticities and consequently a range of simulation results;

b. one general model specification cannot adequately address all problems. For example, an international model which focuses on air travel would naturally exhibit different definitions and parameters than a regional model intended to analyse all modes symmetrically.

Further details on the nature of the demand models is given in Appendix B.

CANPASS-1 SOFTWARE

The CANPASS-2 and 3 software are traditional in concept. The modal systems, either existing or proposed, are predefined and the question is to determine the modal demand response to the offered services. The CANPASS-1 software which is based on the Service Specification Model [6] is quite different in concept in that it is oriented to equilibrium analyses. Inputs to

APPENDIX A

Community file

Table A1

ELEMENT	COMMENT
1. SEQUENCE NUMBER	Each of the 700 communities in the database has its own unique four digit identifying number. The first digit identifies provincial location. In general, the number sequence runs from east to west. Gaps have been left in the number sequence to facilitate the addition of other communities at a later date.
2. CLASS OF COMMUNITY	All communities are classified within a seven tier hierarchical National Community Classification Scheme. This is a functional classification scheme based on the population and facilities available in the community; ranking ranges from "1" for the largest metropolitan centres to "7" for communities of about 1000 population. Class ranking is a surrogate for "inter-action" potential and need for passenger services.
3. NAME OF COMMUNITY (20X)	The name by which the community is listed in the Official List for the 1971 Census of Canada.
4. COMMUNITY TIME BAND DIFFERENCE FROM GREENWICH MEAN TIME	Passenger service arrival and departure times are "local" times. This data element allows the elapsed travel times to be computed.
5. LATITUDE OF COMMUNITY 6. LONGITUDE OF COMMUNITY	These data refer to the population "centroid" of the community, i.e. the "centre of gravity" of the population. The data permit the calculation of intercommunity "airline" distances, and "airline" distance from the population centroid to modal facilities (e.g. airport), as well as allowing computer graphic mapping.
7. POPULATION	The total population of the community is the sum of the populations of the enumeration areas which define the community (see Enumeration Area File). The data were obtained from the 1971 Census of Canada. Preliminary counts from the 1976 Census were also included.
8. PERCENTAGE ENGLISH SPEAKING	The percentage of the population whose mother tongue is English: obtained from 1971 census data.

Note:
This file may be expanded to include (a) data from the 1961 and 1966 Census of Canada, and (b) additional socio-economic data contained on census tapes – tertiary employment, disposable income, and so on.

CANPASS-1 include explicit modal supply functions and modal demand functions. The calibrated demand models serve as the latter. The supply functions take the form of a schedule of service quality (i.e. technology, frequency and performance) which the modal operator would be willing to offer for corresponding ranges in demand.

The potential spatial extent of each modal network is also predefined using a link node format. The function of CANPASS-1 is to determine the service quality of each link in the modal networks (technology, frequency and performance) when modal supply and demand are in equilibrium. The procedure is an iterative one in which the modes compete for a share of the market during each iteration. The final modal network configurations indicate the equilibrium status of each mode given their respective supply functions.

The CANPASS-1 software is operational for multimodal equilibrium analyses using the 1972 pseudo abstract mode model as the "arbitrator" in the intermodal competition. However, the software is still considered experimental at present and considerable scope for refinements and coding efficiencies remain. This type of equilibrium analysis has obvious importance for exploring such concepts as "user pay", commercial viability, subsidy policy, equity and adequacy.

CONCLUSIONS

The synthesis of database, analytical software and passenger demand models makes the CANPASS System an extremely powerful tool. Certainly it is able to support the functions of strategic planning. However, it also constitutes a tool for "imparting a measure of coherence and direction" within the disparate functional groups in a central government agency such as Transport Canada. The database offers the opportunity for rapid accurate information transfer, for a "pooling" of information and for a common definition of problems. The analytical software offers a capability which supercedes empirical "back of an envelope" approaches to policy development and evaluation. Although the system has been operational only for a short time, it has already been well received by professional staff in other areas of Transport Canada and indeed has been used for a variety of purposes. It will be interesting to see if the integrative possibilities of the CANPASS System can be realised and if its role as a management decision system can be put into effect.

Enumeration area file

Table A2

ELEMENT	COMMENT
	Note: *1. This file defines a community in terms of its constituent enumeration areas.* *2. The file is* not *an active file in the CANPASS-3 database, but it is used to compute the value of data elements in the community file.*
1. COMMUNITY SEQUENCE NUMBER	The community's unique identification number.
2. ENUMERATION AREA CODE	Each enumeration area has a unique identification number given in the 1971 Census Official List.
3. LATITUDE OF ENUMERATION AREA 4. LONGITUDE OF ENUMERATION AREA	The latitude and longitude of the population centroid as given in the 1971 Census Official List. These data allow one to determine the location of the community population centroid.
	The data in items 2, 3 and 4 is given for each enumeration area comprising the community.
5. POPULATION OF ENUMERATION AREA	Obtained from 1971 census tapes.
6. PERCENTAGE ENGLISH SPEAKING	Obtained from 1971 census tapes.
7. POTENTIAL FOR EXPANSION	Similar data items to those described in the Community File, provided that the data exist on census tapes.

Facility file

Table A3

ELEMENT	COMMENT
	Note: *1. A facility means an airport, a bus or ferry terminal, or a railway station.* *2. Only important ferries are included.*
1. MODE	Air, bus, rail or ferry.
2. FACILITY SEQUENCE NUMBER	Each facility has its own unique identification number.
3. QUALITY	This is an index number from 1 thru 8 based on ranking within a subjective scale based on the size of the facility. Size was used as a surrogate for quality and number of amenities available at a facility. The element is included as a first attempt to include "quality" in transport system appraisal. Obviously, further research is needed to define a more sophisticated index.
4. NAME	The name by which the facility is usually known.
5. FACILITY TIME BAND DIFFERENT FROM GREENWICH MEAN TIME	Passenger service arrival and departure times are "local" times. This data allows the elapsed travel times to be computed.
6. LATITUDE OF FACILITY 7. LONGITUDE OF FACILITY	These data allow "airline" distance to the community, and inter-facility "airline" distances to be computed as well as permitting computer graphic mapping.
8. ENTRY TIME INTO THE FACILITY	Entry time refers to the period from arrival at the facility (e.g. the car park) to actually boarding the service (i.e. boarding an aircraft).
9. EXIT TIME FROM FACILITY	Exit time refers to the period from deboarding a service to actually departing from the facility.
10. CONNECT TIME AT THE FACILITY	Connect time refers to the minimum time required to transfer from an inbound service to an outbound service at the facility.

Access link file

Table A4

ELEMENT	COMMENT
	Note: *1. An access link may be from a community (centroid) to a modal facility or from one facility to another facility.* *2. It is assumed that the access link attributes are the same in each direction.* *3. The user has the opportunity to insert specific distance, time and fare values, if so required.*
1. ORIGIN	The identification number of: a. the community in the case of a "community to facility" access link; In general, each community is linked to at least one facility for each mode (provided that there is road access) b. the facility in the case of a "facility to facility" access link. In general, facilities are connected only if they are located within the same community.
2. DESTINATION	The identification number of the facility.
3. LINK LENGTH	The "air line" length of the access link which is *computed endogenously* by CANPASS-3 software using the latitude and longitude of the origin and destination.
4. LINK TRAVEL TIME	The automobile travel time to traverse the above link length is computed endogenously by CANPASS-3 software using a travel time formula.
5. LINK TRAVEL FARE	In the same manner as above, automobile travel fare is computed endogenously on the basis of link distance using a cost formula.

Carrier file

Table A5

ELEMENT	COMMENT
	Note: *This file lists the carriers providing scheduled service between any of the 700 communities.*
1. MODE	Air, bus, rail of ferry.
2. CARRIER IDENTIFICATION CODE	A unique two letter identification code for each carrier.
3. CARRIER NAME	The name of the carrier, abbreviated to 20 letters.
4. POTENTIAL FOR EXPANSION	This file could be extended to include such company information as type of ownership, revenue class, and so on.

Scheduled service file

Table A6

ELEMENT	COMMENT
	Notes: *1. This file describes the actual schedule and route structure of every service offered between any of the 700 communities. It consists of a sequence of facilities with associated mileages, arrival and departure times.* *2. A service will normally consist of a single mainline. In exceptional cases, a service may have a branch, i.e. a 4-RDC train may split into two 2-RDC trains. In such cases, the branching service is assigned a unique branch number. Branch characteristics are described following the description of the mainline service to which they are attached.*
1. MODE	Air, bus, rail or ferry.
2. CARRIER	The identification code of the carrier offering the service.
3. SERVICE NUMBER	The identification number of the service or branch to which the subsequent data pertain. Each scheduled service has its own unique number.
5. FACILITY	The identification number of the facility at which service is provided. These are listed in order of distance from the origin point.
6. MILEAGE	The cumulative mileage from the service origin point to the above facility.
7. ARRIVAL TIME	The "local" arrival time at the facility.
8. DEPARTURE TIME	The "local" departure time at the facility.
	The five data elements above are repeated for each facility on the service or branch.

Carrier service file

Table A7

ELEMENT	COMMENT
	Note: This file provides descriptive data about each of the services provided by the carriers other than the actual operating schedule.
1. MODE	Air, bus, rail or ferry.
2. SERVICE NUMBER BRANCH NUMBER	A number which uniquely identifies every scheduled service in the database.
3. CHANGE POINT	This identifies the location in a mainline service or branch service at which some change in the characteristic of the service occurs (e.g. change in equipment).
4. DAYS OF OPERATION	The days on which the service operates are identified by a sequence of seven binary digits representing Monday thru' Sunday. A "1" indicates that service operates on that day while a "0" indicates the absence of service on that day.
5. EQUIPMENT TYPE	This is a two digit code which is keyed to a table of equipment characteristics (e.g. "08" represents a DC-9 aircraft).
6. SEATING CAPACITY	The number of seats provided on each log of an itinerary.
7. POTENTIAL FOR EXPANSION	This file may be extended to record historic service-related data, e.g. operating cost, subsidy, revenue, passengers carried, energy consumed. The file could also conveniently record historical data, if required.

Highway link file

Table A8

ELEMENT	COMMENT
	Note: This file describes the highway system connecting the 700 communities in the database in terms of nodes and links. A link is identified by the nodes at the beginning and end of the link. The characteristics and attributes of each link are then recorded.
1. "A" NODE	The number of the node at one end of the link (A-B).
2. "B" NODE	The number of the node at the other end of the link (A-B).
3. LINK LENGTH	The distance from node A to node B along the highway link.
4. NUMBER OF LANES	The *total* number of vehicle lanes provided.
5. AVERAGE OPERATING SPEED	The average operating speed limit on each link of highway network. Travel times can be calculated from this information.
6. AADT	The Average Annual Daily Traffic along each link.
7. SADT	Summer Average Daily Traffic.
8. WADT	Winter Average Daily Traffic.
9. POTENTIAL FOR EXPANSION OR TRAFFIC FLOWS	This file may be extended to include other physical inventory data elements, if required, such as shoulder widths, speed limits and weight restrictions.

APPENDIX B

Mathematically, the models are quasi-direct in form. They are essentially direct in that the demand for travel by mode is related to attributes of the transport system and the socio-economic environment by a single equation. However, the models exhibit a separability between the demand for travel, independent of mode, and the choice of mode. This separability is imposed and exploited in the estimation of parameters which is partitioned into two stages, the second of which is linked to the first by substitution of a calibrated modal impedance term.

The majority of the models are of the following structure:

$T_{mht} = T_{ht}(A_{ht}, C_{mht}) \cdot S_{mht}(C_{mht})$

where T_{mht} = the demand for travel by mode m on city pair h at time t

$$T_{ht} = \sum_m T_{mht} \tag{1}$$

S_{mht} = the share of travel using mode m

A_{ht} = a vector of socio-economic activity variables

C_{mht} = a vector of modal attributes

The separability of (1) gives rise to the following additive property of the modal attribute elasticities:

$$\frac{\partial T_m}{\partial C_{mk}}\left(\frac{C_{mk}}{T_m}\right) = \frac{\partial T}{\partial C_{mk}}\left(\frac{C_{mk}}{T}\right) + \frac{\partial S_m}{\partial C_{mk}}\left(\frac{C_{mk}}{S_m}\right) \tag{2}$$

Thus, for example, the fare own elasticity of demand by mode is composed of the sum of two effects: the elasticity of total intercity demand, and the elasticity of market share, of mode m with respect to its own fare.

Whereas the models may be estimated using either cross-sectional or time-series data or both, the work to date has employed only cross-sectional data from some 230 city pairs in Canada for 1972 and 1976. In terms of the modal share component, one form of the model [7] is specified by:

$$S_{mh} = U_{mh}\left[\sum_m U_{mh}\right]^{-1}$$

$$\text{where } U_{mh} = \exp\left(\alpha_{om} + \alpha_1 C_{mh}^{(\lambda_1)} + \alpha_2 H_{mh}^{(\lambda_2)} + \alpha_3 D_{mh}^{(\lambda_3)}\right) \tag{3}$$

$$C_{mh}^{(\lambda_1)} = \frac{C_{mh}^{\lambda_1} - 1}{\lambda_1} \quad \text{is a Box and Cox transformation}$$

C_{mh} = travel cost or fare by mode m on city pair h
H_{mh} = travel time in hours
D_{mh} = departure frequency per week

The quasi-abstract model with generalised functional form possesses own-attribute modal share elasticities of

$$\frac{\partial S_m}{\partial C_{mk}} \left(\frac{C_{mk}}{S_m} \right) = \alpha_k \, C_{mk}^{\lambda_k} \, (1 - S_m) \tag{4}$$

which may be computed either on a city-pair specific, or city-pair class specific, basis or at the sample mean of the observations on the original variables.

Aggregate demand for travel is similarly specified as

$$T_h^{(\lambda_0)} = \beta_0 + \beta_1 P_h^{(\lambda_1)} + \beta_2 L_h^{(\lambda_2)} + \beta_3 Y_h^{(\lambda_3)} + \gamma U_h^{(\lambda_4)} \tag{5}$$

where P_h = population product for city pair h
$L_h = 1 - | L_i - L_j|$ a linguistic pairing index for the bilingual case
L_i = proportion speaking English in city i
Y_h = average per capita disposable income
$U_h = \sum_m U_{mh}$ an impedance index

The elasticity of (5) with respect to a modal attribute is therefore

$$\frac{\partial T}{\partial C_{mk}} \left(\frac{C_{mk}}{T} \right) = \alpha_k \, C_{mk}^{\lambda_k} \, T^{-\lambda_0} \, \gamma \, U^{\lambda_4} \, S_m \tag{6}$$

Both (4) and (6) reduce to conventional cases for $\lambda = 0$ and the generalised unimodal gravity model if, in addition, $S_m = 1$. Detailed empirical analyses of the effect of the specification of functional form on elasticities are available elsewhere. [8]

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