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INTERCITY PASSENGER TRANSPORT ENERGY
CONSUMPTION IN THE QUEBEC CITY-WINDSOR CORRIDOR

by

Alan D. Taylor, B.Eng. (Carleton University)

A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfillment of the requirements
for the degree of
Master of Engineering

Department of Civil Engineering
Faculty of Engineering
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February 1981

The undersigned recommend to
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"Intercity Passenger Transport Energy
Consumption in the Quebec City-Windsor Corridor"
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Abstract

This thesis discusses intercity passenger transportation energy consumption in terms of a framework for energy analysis and the results achieved. An examination of the factors involved in energy consumption by transportation is made. Problems in the estimation of basic energy efficiency data are discussed. A demonstration of the process of calculating energy consumption on a location-specific basis is made.

A system of seven intercity links in the Quebec City-Windsor corridor was selected as the location for analysis. Data on 1976 travel demand, socioeconomic variables and energy efficiency were gathered. Projections of socioeconomic variables for 1986 and 1991 were obtained. Seven scenarios illustrating possible future developments in the transportation system were developed. Using a demand model, estimates of 1986 and 1991 travel demand under each of the scenarios were made. Calculations of energy consumption and efficiency were made on a link and mode specific basis. Energy calculations included direct and indirect energy, for line-haul and access/egress portions of the intercity trip.

The results are presented both as totals of all links and on a link-by-link basis.

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The Canadian Ministry of Transport provided the demand model and basic data on the system. The Canadian Transport Commission provided data on terminal access and egress. Air Canada and Canadian National Railways provided data on fuel consumption by aircraft and train.

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Chapter 1

Introduction

1.1 Background and Objectives

Intercity passenger transportation in Canada is almost completely dependent on petroleum fuels. Steadily increasing prices for oil and the prospect of the ultimate depletion of world oil resources make petroleum conservation an important area for study.

Studies of energy consumption on a national or regional scale, using averages of aggregate consumption and productivity measures, are not totally valid for planning purposes. Energy consumed by some services may differ significantly from the average. The impacts of policy changes intended to save energy on the suppliers and users of transportation will be extremely hard to forecast with any accuracy.

An energy analysis methodology that accounts for all factors of demand and energy consumption is needed to plan for energy conservation within the framework of existing services.

Energy conservation can be encouraged by technical and systemic changes in the supply of transportation and by reducing or shifting demand for transportation away from energy inefficient modes.

The objectives of this thesis are: (a) to illustrate a methodology for energy analysis and, (b) to show how the technical, system supply, and demand measures to encourage energy conservation can be examined.

A demand model in association with Windsor to Quebec City transport system and socioeconomic data were used to predict travel demand and the response of passengers to demand management measures. The predicted volumes were used with current and projected energy intensity estimates to calculate energy consumption under different supply scenarios.

1.2 Organization

Chapter 2 discusses the study rationale, location and available techniques. Energy consumption of the various modes, the types of energy consumption, and the methods for estimating energy consumption are discussed.

Chapter 3 contains a description of the study locale in 1976 and scenarios for the possible future system to be used in the demonstration of the methodology.

Chapter 4 details the methodology with descriptions of the demand model and the inputs to the demand and energy consumption calculations. Resulting travel demand and energy consumption estimates are presented.

Chapter 5 includes a summary and discussion of the results of the demand and energy calculations.

Chapter 6 includes a summary of the thesis, and conclusions. In addition, extensions or recommendations for further study are made.

Chapter 2

Study Approach and Methodology

2.1 Study Rationale, Location and Available Techniques

The initial set of activities in this research were: to collect data and show a method for calculating energy impacts of technological change and demand management in an intercity multimodal passenger transport system. A series of characteristics that would be desirable in a system to demonstrate the objectives of this thesis were developed.

In an energy shortage situation intercity transportation volumes are more likely to be affected than urban transportation. Sacco and Hajj¹ found that urban automobile travel was relatively insensitive to fuel price and shortage problems. Slettemark² and Crow and Savitt³ both found relatively large modal shifts and travel reductions in intercity travel markets. Intercity travellers have more choice of competing modes and have more freedom in deciding whether or not to travel than an urban or suburban traveller on a journey-to-work or shopping trip. For these reasons an intercity study would provide a better opportunity to examine modal shift and demand reduction strategies.

The potential for modal shifts in Canadian intercity markets is greatest in short-haul (0-500 miles) links. This market was 94.2% of the total intercity passenger market in 1975. Over 75% of automobile trips were less than 100 miles long, 60% of bus trips were less than 100 miles long, 50% of air trips were between 100 and 500 miles long, and almost

60% of rail travel was of lengths less than 400 miles.⁴

In Canada there are two major intercity corridors: Edmonton-Calgary and Quebec City-Windsor. The Edmonton-Calgary corridor has only two major city nodes. The Quebec City-Windsor corridor is in the most densely populated area of Canada and offers a larger number of intercity links. A number of studies have been done in both corridors but data availability, especially access data, appeared more complete in the Quebec City-Windsor corridor. This thesis therefore focuses on the Quebec City-Windsor corridor.

To study the energy implications of various policy and other changes in future years an intercity demand model to predict travellers' responses is needed. The demand model must be multimodal, including at least automobile, rail, bus, and conventional take off and landing (CTOL) modes. Inclusion of a capability of examining the short take off and landing (STOL) mode separately from CTOL could be desirable.

For reasons discussed later access characteristics are included in energy calculations. Additionally, travel decisions are based on door-to-door travel considerations. It is therefore desirable that access characteristics be included in the demand model formulation.

A model calibrated by the Strategic Planning Group of Transport Canada was obtained. The PERAM model was used in the Southern Ontario Multimodal Passenger Studies^{5,6}.

This model was calibrated for the Quebec City-Windsor corridor, is multimodal, (but does not include STOL) and accounts for access characteristics. The model is more completely described in Chapter 4 and Appendix C.

2.2 Energy Consumption Calculation Process

The calculation of energy consumption is conceptually quite straightforward. Once figures on demand and modal split have been obtained it is merely necessary to multiply the transportation system output (actual passenger miles) by the appropriate energy intensities. The determination of the energy intensities is more difficult. The basic energy calculation process is shown in Figure 2.1.

Direct energy is defined as the energy consumed directly for movement, ie., in general, the fuel consumed. Indirect energy is defined as energy consumed in vehicle manufacturing and maintenance, and infrastructure construction, maintenance and operation, and energy to produce fuels. A recent case study⁷, done at Carleton University, found that while direct energy is the largest portion of total energy consumption, indirect energy made up no less than 26% of energy consumption*.

The above referenced study found that access to intercity public mode terminals was, for CTOL 6.6%, rail 4.9% and bus 15.4%, of total energy consumption. Obviously indirect and access energy should be included in energy analysis. None of these figures include infrastructure

* This was the indirect proportion of CTOL mode's consumption. Other modes were: rail 33%, bus 30%, and auto 34%.

FIGURE 2.1

ENERGY
CALCULATION PROCESS

construction energy as the system was essentially in place. However, if the construction of a new mode or major improvements to an existing mode are contemplated, infrastructure construction energy can become a major component, for example construction of a high speed MAGLEV system⁸.

Exact consumption by each vehicle of each mode on each link would give exact total consumption values. This level of detail is impossible to obtain and unnecessary as well. Figures that reasonably approach that level of detail can be obtained.

The large number of calculations required for energy analysis led to the development of a computer program. Chapter 4 and Appendix D. contain a more detailed description of the program.

The calculations involved in demand and energy models provide opportunities to derive other system related quantities as well. Traveller cost and traveller time are inputs to the demand model and totals and averages are then simple to calculate. The avoidable and total cost of a system is simplified once demand and modal split are obtained. These quantities, additional to energy quantities, are a byproduct, as it were, of using a demand model in an energy study.

2.3 Travel Mode Energy Consumption and Opportunities for Improvement

Direct or fuel energy consumption is the largest portion of total transportation energy consumption. Consumption depends on three types of factors: technical, systemic and operational.

Technical factors concern the vehicle characteristics, systemic factors concern the characteristics of the links, i.e. where the vehicle is used, and operational factors concern how the vehicle is used within its operating range.

Energy from fuel is converted to work by some sort of an engine overcoming resistance to move a payload. Thus there are three technical areas. Thermopropulsive or conversion efficiency describes how much of the energy available in the fuel is converted to work by the engine. Structural efficiency is the ratio of payload to vehicle weight. The resistance to be overcome is principally friction and acceleration resistances.

Systemic factors include distance to be travelled by the vehicle, distance of access to the vehicle, stops or congestion effects en route, route circuitry (the ratio of actual distance travelled to the great circle or effective distance) and characteristics of the route such as roadway profile and alignment which interact with the technical aspects of the vehicle.

Operational factors influencing energy consumption include load factors, operating speeds and acceleration rates, and measures taken to reduce consumption such as altered ground procedures for aircraft.

Automobile

Technical Factors: Automobile energy consumption is affected by:

1. Engine technology - diesel or gasoline engine, stratified charge or conventional ignition, lubrication.

2. Structural efficiency - materials, overall size, and design.
3. Aerodynamic drag - shape and size of vehicle.
4. Rolling resistance - tires, pavements, vehicle weight.
5. Inertia effects - speed changes, roadway alignment, vehicle weight.
6. Transmission losses - automatic or standard transmission, bearing friction.
7. Accessories - air conditioning, power steering, emission control, and safety devices.
8. Weather - rain, snow, heat and cold, wind.

Government enforced emission and safety standards decreased automobile fuel efficiency for a number of years. Later, fuel efficiency standards were introduced as well forcing auto makers into intensive study of all factors of automobile design.

Engine technology has been a focus of study. Diesel engines are potentially more efficient than gasoline engines because they run on a more efficient thermodynamic cycle. Diesel performance is usually inferior to gasoline engine performance and diesel engines are generally heavier. Catalytic converters allow the use of more efficient but higher polluting engines by processing the exhaust to cut down on pollutants. Stratified charge engines, electronic high-energy ignition, the use of microprocessors to instantaneously monitor ignition timing and fuel metering, and improved valving reduce the amount of unburned fuel that passes through the engine. Improved lubricants and bearing materials and tolerances can reduce internal power losses. Overdrive transmissions

match engine speed to required power output and improve economy. More novel efforts include engines that reduce the number of cylinders working when loads are low and flywheel driven vehicles with constant speed engines to maintain the flywheel's spin. A more basic method of improving fuel efficiency is to keep the engine in tune.

Structural efficiency has also received attention. Vehicles are smaller and lighter than in the past, yet they have similar capacities for people and baggage. Use of plastic, aluminum, and high strength steel has reduced weight. Front wheel drive saves interior space and reduces weight by eliminating the heavy propeller shaft. Glass and sheet metal are thinner in modern vehicles. Refinements in design of safety devices have enabled weight reductions.

Aerodynamic qualities have been improved. Body styling changes and improving the design of parts that interrupt smooth air flow, such as side mirrors and bumpers, in addition to the direct effect of reducing frontal area by reducing overall size reduce drag. Trucks on the other hand are usually as large as the law allows to provide necessary capacity. Improved truck aerodynamics may require a reduction in payload which may not really save any fuel. Devices for improving the airflow over a truck-trailer combination have become very popular.

Radial tires have significantly lower rolling resistance than conventional tires. Correct inflation is important. Lighter vehicles imply less flexing of tires and reduction in energy use. Pavements in good condition require less energy than rough payments.

Many speed changes, accelerations and breaking, use more energy than a constant engine speed. Roadways with many horizontal curves will require more fuel than straight roads of the same length, because curves slow vehicles down leading drivers to react by increasing the throttle to restore speed. Vehicle mass, including wheel mass, is also important in considerations of inertia effects.

Automatic transmissions are reported to require 4 to 10 percent more energy than standard-drive transmissions⁹. Improved design, especially of the fluid clutch in automatic transmissions, could improve economy. Lubrication and bearing performance could perhaps also be improved.

Accessories such as air conditioning add weight to the vehicle and require power to drive them. Power seats and power windows consume very little power. Power brakes working off of engine vacuum add only weight to the auto's fuel consumption. Air conditioners consume energy even while turned off since the driving belts are always turning when the engine is on.

Weather conditions influence fuel consumption. Engines can be better designed to allow for poor conditions. Cold engines require more fuel for the same power output. Block heaters could be important energy saving devices, even including the power to run them, but their influence is mostly limited to urban trips. Heating the intake air by crossing it over the exhaust manifold when weather is cold also improves performance and fuel economy. Driving through snow requires much extra energy due to the increased rolling friction.

Systemic factors:

1. Grades: roadways with many grades require more fuel than more level roadways because energy spent to climb hills is not all restored on descent. Horizontal curves also have effects as mentioned previously.
2. Traffic Conditions: congested roadways will cause increased fuel consumption, especially if many passing manoeuvres occur.
3. Trip Length: longer trips are more efficient because the effects of higher consumption urban travel are reduced.
4. Circuity: the effective distance travelled from point to point is the great circle distance. Because highways are not built in straight lines, longer real distances must be travelled. When comparing one mode to another circuity can be an important factor in equalizing the outputs of modes.

Prospects for improving fuel consumption by altering systemic factors are small. Improved highways with lower grades and more direct routings would improve fuel economy but the improvements may not be worth the costs in energy and money.

Operational factors:

1. Speed: automobiles are most efficient at a particular speed that will vary from vehicle to vehicle. This speed is in the range of 40 to 50 mph. At higher speeds increased wind resistance requires more fuel. The reduction of speed limits from 70 to 55 mph led to improved fuel consumption^{10,11}.

2. Variations in speed: a constant fuel flow rate gives better fuel economy than is given by accelerations and braking.

3. Load factor: the difference in fuel consumption due to the added weight of more passengers is relatively minor. In terms of output, passenger-miles, more passengers in the automobile greatly improves the fuel consumption. Load factors are higher in recreational travel than in business travel.

Operational factors offer some opportunity for improving fuel efficiency. The imposition of speed limits closer to the auto fleet optimum speed would lead to reduced consumption directly. Indirectly, if this reduction in level of service led to less trips or to mode shifts to more efficient modes, further fuel consumption gains would be made. Educational efforts to improve driving habits have desirable effects.

Intercity Bus

Technical factors: The intercity bus is similar to the automobile in its technical characteristics. Buses have become larger and heavier over time and are now at the maximum length, 40 feet, permitted by highway laws. Seating capacity is around 46 persons. The use of aluminum in much of the body has given the bus good structural efficiency. Diesel engines in use now are regarded as quite efficient and many intercity buses use manual shift transmissions (which are more efficient than automatic transmissions).

Aerodynamic drag and road friction appear capable of reduction. With vehicles as large as allowed the shape of the vehicle approaches

a box, which ~~does~~ not have good aerodynamic properties.

Alternate engine technologies ~~may~~ become practical, and the larger space available in a bus body may aid this.

Systemic factors: are very similar to those of the automobile and offer little opportunity for further improvement.

Operational factors: again these are similar to the automobile. Speed affects the fuel consumption greatly. Consumption is approximately doubled between 50 and 70 mph⁹. Reductions in speed may be possible but are hindered by marketing considerations. Load factors for bus, at least for "limited" services between major points, appear quite good. The relatively small size of the vehicle simplifies the achievement of good load factors.

Intercity bus, already a relatively efficient mode, offers little opportunity for fuel economy improvement. Evolutionary changes in drive train and engine in the 1980's could lead to economy improvements of up to 15% over the 1974 consumption^{12,13}.

Intercity Rail

Technical factors: Energy consumed and power produced by a diesel-electric powered train can be allocated to: aerodynamic drag, acceleration losses, rolling resistance, track losses, auxillary losses, thermal losses and transmission losses.

Rail horsepower is the power available at the wheels which is used to do the real work of the train: overcoming aerodynamic, acceleration and track losses, and rolling resistance.

Aerodynamic and acceleration losses have been defined in the section on the automobile. Rolling resistance is the rolling friction and other losses due to the track structure such as the swaying of cars and truck hunting. Track losses are losses from curve resistance and grade resistance.

Auxillary losses are the energy consumed to power devices such as cooling fans, air conditioning and provision of heating (electrical or steam).

Thermal losses are the losses which occur in the diesel engine. Transmission losses are the losses which occur between the input of the traction motor and the rail horsepower.

Passenger trains are designed aerodynamically but as drag increases with the square of the velocity a maximum practical speed is soon reached. The limits of adhesion of steel wheels on steel rails, combined with the aerodynamic factors mean that at extreme speeds, say 150 mph, the energy consumption of aircraft is approached, at a much higher cost than for aircraft. Aircraft operate in lower air densities at altitude.

The structural efficiencies of trains may be poor. Older trains, with much steel in their construction, require more energy than modern lightweight trains. Non-revenue cars, such as cafe and lounge cars, impose a penalty on energy efficiency by adding non-productive weight. (of course, these cars are productive in the sense that without them in the train many travellers may chose alternate modes)

Systemic factors: Again circuitry has an influence here. Depending on the route the train may, or may not, have a lower circuitry than the highway. The condition of the track influences fuel consumption several ways. Rough track requires more energy to overcome friction and roadbed effects. Rough track will also make necessary speed reductions which reduce the level of service and therefore the patronage. With less travellers and lower load factors the energy consumption per passenger increases. Rough track also means more speed changes, which increase consumption.

Operational factors: Diesel-electric locomotives are rarely switched off, and fuel consumed while idling is lost completely. In cold weather this prevents freezing of cooling water and start up problems. In warm weather locomotives can be switched off without problems. Block heater type coils could be installed for cold weather¹⁴.

Improved load factors would be instrumental in improving energy efficiency. This will require service improvements, such as increased speeds, which would increase fuel consumption. The better load factors may offset this increase. Track improvements needed to obtain increased speeds would reduce fuel consumption as mentioned above.

Improvements in diesel engine power plants and electric generators may reduce power to weight ratios, which would improve fuel consumption. Advanced suspension systems, such as LRC's system, enable higher speeds and improved level of service to be attained on conventional track. These systems add weight however.

Air Transportation: Technical, operational and systemic factors are very inter-related in air transportation. Substantial energy savings are possible by 1990¹⁵. New aircraft and evolutionary development of existing aircraft will improve consumption.

Fuel efficiency depends on a number of factors such as engine design (specific fuel consumption), air frame design (structural efficiency), aerodynamic design (drag, lift), control systems (active controls), cruise speed and altitude, take-off, landing and ground procedures including ATC procedures, seating arrangement, and load factors.

Almost all commercial air transport in Canada is jet powered, most by pure jets as opposed to turboprops. The original jet engines were low-bypass ratio designs limited by turbine blade materials technology. High-bypass ratio engines are used in most new aircraft. These have better specific fuel consumption characteristics and have been designed to be quieter and less polluting. As aircraft with high-bypass ratio engines eliminate the older engine technology aircraft fuel consumption for the system will improve. A further development of jet engines is the prop-fan engine - a type of turbo prop with a radically different propeller design. Forecasting the resulting energy improvement from

this proposal is difficult because the whole aircraft design is involved. Studies have indicated the saving may be substantial, especially at low altitudes and speeds of short to medium haul links^{15,16}. This new engine technology is not likely to be in service until the 1990's.

Prospects for near-term improvements in engine design arise from engine component improvement. Improvements could be quickly added to existing engines, either new or in engine over-hauls. Performance deteriorates over time and has become more serious with high-bypass engines. Some of the deterioration comes from fan nicks, seal deterioration, compressor tip wear, warped combustors and turbine blade erosion. Improved maintenance and tuning of engines, and new turbine blades and coatings, new seal designs, and exhaust mixer nozzles are forecast to reach a 5% improvement in specific fuel consumption over present new engines.

Aerodynamic research is ongoing in two technical areas: energy efficient transport and laminar flow control. The energy efficient transport involves the technology for new high aspect ratio, super critical wings, winglets, improved engine/airframe integration, digital avionics, and active controls for stability improvement and gust/maneuver load control. Active controls are devices that automatically move control surfaces to reduce loads on the aircraft structure. This reduces the needed size of control surfaces and reduces drag and structural weight. The energy efficient transport program will have near to far term impacts.

Laminar flow control research is directed at improving the airflow over the aircraft surfaces. This involves surface contamination, airfoil and wing design, suction distribution, and manufacturing quality. Laminar flow control has far-term prospects.

Structural improvements involving the use of composite materials, already in much use in military aircraft, will have mid to far term impacts through weight reduction. Composite materials are filaments of carbon or boron embedded in a matrix of epoxy or metal and are light for their strength.

In aircraft operation fuel economy improvements are possible through higher density seating, higher load factors, and improved operation. Much has already been done by increasing the number of seats per aircraft. This includes the wide-body technology as well as up-grading existing narrow-body aircraft. Of course, these changes are not effective without increasing the number of passengers per flight.

Operational measures improve fuel economy without any comfort and convenience penalty for the passenger. Aircraft are not always flown at a fuel optimum cruise speed because operators are interested in minimizing direct operating costs, not fuel consumption. As fuel becomes more expensive, it can be expected that airlines will approach minimizing fuel consumption. Fuel rationing, regardless of cost, would emphasize this trend even more. In the short ranges that exist in the corridor, cruising is not as significant as in long ranges. Loading the aircraft closer to the aft center of gravity would reduce trim drag. Removal of unnecessary equipment would reduce the operating empty weight.

Air traffic control procedures could be altered. MLS (microwave landing system) will ease congestion and reduce delays by reducing runway approach distances. Parallel runways could also be used.

General aviation traffic could be shifted away from major airports thus reducing delays and large craft fuel consumption. On the ground aircraft could taxi on fewer engines or be moved by ground vehicles.

Systemic factors have less potential for reduction of fuel consumption. On longer routes circuitry is low, but in short distances such as found in the corridor the circuitry may be high. This is a consequence of routing for noise abatement or air traffic control safety purposes. Perhaps the circuitry may be safely reduced.

2.4 Direct Energy Consumption Estimates

Airline pilots need to know the amount of fuel needed to fly to their destination. The amounts used are relatively predictable for each aircraft type and each link flown. Indeed this level of detail may be necessary because consumption on a unit output basis can vary so greatly.

The direct energy consumption for the aircraft used on particular links was provided by Air Canada¹⁷. Where the aircraft chosen for a particular link for this thesis did not match the Air Canada data, calculations using data in Khan et al were used⁷. Use of different aircraft than Air Canada suggested is discussed in section 4.3.

The automobile fleet fuel consumption has large variations between drivers and vehicles. Fortunately the stage length and highway profile, at least in the corridor, seem to have relatively little effect on average fuel consumption

Government mandated fuel economy standards simplify the determination of future year fuel consumption. The Environmental Protection Agency (EPA) of the U.S.A. and Transport Canada tests of new car fuel economy offer an opportunity to estimate fuel consumption. The E.P.A. figures have to be adjusted to make reasonable over-the-road estimates. A factor of 1.14 is commonly applied. The new car figures for any year do not reflect the on-the-road fleet consumption. Assumptions on vehicle sales and vehicle life-times can be made to make possible adjustments to calculate fleet consumption. It is generally assumed that new car averages will be the fleet averages in five years^{18,19}. Thus for 1990, the 1985 new car averages would be used.

For 1976, data were not available on fleet fuel economy. N. D. Lea and Associates estimated 1975 economy⁹. The fuel economy of the fleet fluctuated through the early 1970's because of the addition of pollution controls and then imposition of fuel economy standards. In 1975 the on-the-road fleet average was approximately the same as the new car average.

Since data for 1976, 1986, and 1991 were not available, figures for 1975, 1985, and 1990 had to be used.

Intercity bus consumption of fuel is more simple to obtain than automobile consumption. The intercity bus fleet is made up of a smaller variety of vehicle models and is controlled by a relatively few business concerns. It is theoretically easier to obtain fuel consumption data from a few businesses who keep records on their fleets' fuel consumption

than from a mass of automobile owners and users.

Consumption reported by IBI²⁰, and the U.S. Department of Energy²¹, was used to develop 1976 and 1986 fuel consumption figures. The IBI figures were compiled from manufacturers' statements and operators' experience. As mentioned previously in this chapter, fuel economy improvements of up to 15% are forecast by 1990. An assumed improvement of 10% was regarded as a safe estimate for 1991.

Passenger rail fuel consumption data is not readily available. Passenger trains run with different consists at different times of the week or year, on the same link. Mechanical details make the measurement of actual fuel consumption technically difficult.* Fuel serves as ballast as well as engine fuel. Railroads have historically not been particularly interested in fuel consumption on any detailed level. Train performance calculators, which are complex formulas for calculating speed and other performance data as well as fuel consumption require enormous amounts of detail on train consist and track profile and alignment. Annual consumption data can be averaged out to provide reasonable energy intensity figures. For future years, introduction of LRC equipment, which has a single manufacturer and a limited number of consists, enables more reliable data to be obtained.

* e.g.: Railway diesel engines use fuel as part of the engine cooling system. Some of this cooling fuel is drawn off to provide fuel for combustion. Mechanically metering this drawn-off fuel is difficult.

Data on existing rail service, by train and link, was provided by CNR^{7,22,23}. Seat weighted averages of the fuel consumption were used for energy calculations.

For 1986 and 1991, LRC service was assumed. According to a 1977 announcement, the first link to be LRC equipped is Montreal-Quebec City²⁴. Simulation tests and operational experience from the New York City-Albany run, Tempo service in southern Ontario and data from the LRC manufacturer was used to calculate the consumption figures^{10,25,26}.

2.5 Indirect Energy

The calculation of indirect energy consumption is more complex than calculation of direct energy consumption. Indirect energy consumption is:

... the depletion of energy resources associated with the manufacture [and maintenance] of vehicles and guideways which compromise the system. All of these contributions must, in turn, reflect primary resources: the operation energy must include the energy to refine petroleum production..., while the manufacture contribution must trace the mining of the ores from which the metallic components are made.⁸

The indirect energy contribution to the manufacture of vehicles, say, has to be "amortized" over the life of the vehicle to yield an energy intensity useful for calculating the energy used in any one trip.

Energy that has been "sunk" into existing infrastructure should not be included in any planning exercise because that energy is lost; it cannot be used for other purposes (unless there is an alternate use for the

infrastructure that will recover some energy value). In effect sunken energy is a non-avoidable energy-cost and of no use in comparisons between planning alternatives. Details of indirect energy calculations are given by various sources such as Fels⁸, and IBI Group²⁰. More detailed description of indirect energy types is contained in section 4.7.

2.6 Calculating Indirect Energy Consumption

Energy consumption analysis has some similarity with financial analysis. However, there are no recognized accounting methods for energy such as are available for financial analysis. Two methods that are common are process analysis and input/output analysis.

Process analysis is conceptually the more simple of the two methods. The energy consumed in each step of the manufacturing process is found, and then totalled up for the finished product. This is a lot easier said than done.

The number of steps can become enormous. Manufacturers will generally have suppliers of parts, components and other semifinished goods. The suppliers have suppliers, and the analysis may be recursive. Truck parts may arrive on trucks produced by the factory they are supplying.

There is a problem of allocation of energy use to individual products. If there is any differentiation among the outputs of a manufacturing process more detail is required to assign energy consumption to each type of output. This problem is similar to the

allocation of maintenance costs of railway lines that are shared by freight and passenger trains. Even if detailed analysis of the manufacturing process revealed the energy used there, what method can be used to allocate the "overhead" energy costs, costs such as energy used for heating administrative offices?

A further problem is that the network of supply paths, each with an energy impact, will be extremely large and complex. For example, the steel in an automobile comes from iron ore mined by a steel machine, which was made by steel machines. Thus, the inputs can be traced back into time. One reasonable simplification is to consider only energy not yet spent. Energy that has been used to construct steel mills or other factories is "sunk" and virtually non-recoverable. Therefore it has no influence on future energy consumption. If new construction of plants or facilities is required, then the energy used in that construction is significant and should be included in the analysis.

However, even with a cut-off of sunken-energy, the network could still be very large. The analysis will have to be cut off at some point, and whatever energy used in the processes not examined will be not included. This truncation error may be small, but will still exist.

Input/output analysis is a more aggregate enumeration of consumption than process analysis and is more simple to use. Monetary input/output tables of coefficients show, for a dollar of output of a particular industry and product, the inputs from other industries necessary for the production of that product. When the table is complete,

all feed-back or self-consumption effects are included. Energy input/output coefficients are similar, showing for each unit of output, the direct energy input. There are problems in actually using this method.

Input/output tables of energy consumption were developed by Statistics Canada in the Census of Manufacturers. The Canadian energy input/output tables contain 211 industries and 684 commodities. Not all of these are directly related to transportation. The coefficients were developed from the 1966 Census of Manufacturers, and therefore represent the technical and economic conditions of the time. The commodities are aggregated and the energy cost of a product is a national average.

The tables provide energy consumed per dollar of value added for each industry. This means the tables assume the energy intensity per dollar of output is equivalent for all outputs of an industry. When some outputs are made by highly mechanized processes, and others are made with much hand labour, which is less energy intensive, an error is created.

These are aggregation problems. Another problem is the conversion of energy terms to monetary terms. If prices for the same product vary, the input/output method will show a variation in energy consumption that is not real.

The IBI and other studies use a combination of these two methods. A one-stage process analysis is used to determine the inputs to the

production, and then input/output tables are used to determine the energy costs of the inputs. More detailed process analysis on any aggregation problem portion of the system can be used.

This combination reduces the errors but is still subject to problems with different valued products of similar processes showing different energy costs, for example high-strength versus regular steel.

There is also the problem, common to any approach, that manufacturers in competitive situations are not eager to reveal details of their production process.

2.7 Useful-life, Life-time and Energy Flows

The energy to construct a vehicle or a guideway is consumed when it is built. The product, and thence the energy, provide transportation output over the life of the product. How then is the energy used to be related to the transportation output? To assign energy values to such as passenger-miles one approach is to calculate the useful-life of the product in terms of passenger-miles. The energy consumption rate is then expressed as energy per passenger-mile.

It seems clear that of two options for provision of transportation, one with a high initial energy cost and low running energy cost, the other with low initial and high running energy costs, which use the same total energy, the option with high initial cost is more sensible if energy is to become increasingly scarce.

If the two options have different useful lives, to compare them the energy must be assigned to output or else the comparison cannot be made.

It is also useful to make a total of construction energy, which is consumed now, or at some definite point, separately from the totals of maintenance and operating energy, which are consumed gradually.

2.8 Energy Types

Another question is the substitutability of energy types. There is no shortage of hydro-electric power in Ontario. Petroleum based fuels are subject to supply problems now, and eventually to real shortages. Therefore it would be best to monitor energy requirements separately by type. Most direct transportation energy now is petroleum based energy. The methodology for calculating indirect energy makes the separation of energy types difficult. Therefore, most studies, including this one, consider only total energy, in some common unit, such as British thermal units.

Chapter 3

1976 System and Future Scenario Descriptions3.1 The Quebec City-Windsor Corridor

The area between Quebec City and Windsor is the most densely populated area in Canada. The major city pairs are all within 500 miles of each other. Links of less than 500 miles provide opportunities for significant modal shifts. Time advantages of any mode over any other mode are small enough to enable pricing and other strategies to have significant impact.

Accordingly seven city pairs in this region were chosen for detailed study of possible energy efficiency improvements. The city pairs selected and 1976 origin-destination traffic are shown in Table 3.1. In these markets automobile carries 70% of the traffic, rail 7%, bus 12%, and CTOL 10%, approximately. Individual links vary considerably from this modal split as shown in Table 3.2.

There was good service provided to the corridor in 1976. All city pairs were linked by all four modes. 1976 load factors were not available in a complete form from a single source, therefore 1977 load factors were used in this study. There were no large changes to the system to make 1977 load factors unrepresentative of 1976 service.

Table 1

1976 Origin-Destination Passenger Traffic
(thousands of one-way trips)

City Pair	Auto	Rail	Bus	CTOL	Total
Montreal-Quebec City	4675	78	702	117	5572
Montreal-Ottawa/Hull	2549	173	675	62	3459
Montreal-Toronto	750	416	207	948	2322
Toronto-Ottawa/Hull	1100	70	283	480	1933
Toronto-Windsor	790	118	45	97	1049
Toronto-London	2141	293	135	30	2599
Toronto-Sudbury	300	31	122	90	543
Total Trips	12305	1179	2169	1824	17477
Percent of Total Trips	70.4	6.7	12.4	10.4	100.0

Notes: Some rounding may occur in the above figures.

Toronto-Windsor rail was estimated from Toronto-Windsor/Detroit rail volume.

Montreal-Ottawa/Hull does not include passengers carried on the Airtransit STOL service.

Montreal-Quebec City rail from CTC. Excess from rail is credited to other modes proportionally.

Source: Reference 7.

Table 3.2

1976 Origin-Destination Modal Splits

(%)

City Pair	Auto	Rail	Bus	CTOL
Montreal-Quebec City	83.9	1.4	12.6	2.1
Montreal-Ottawa/Hull	73.7	5.0	19.5	1.8
Montreal-Toronto	32.3	17.9	8.9	40.8
Toronto-Ottawa/Hull	56.9	3.6	14.6	24.8
Toronto-Windsor	75.2	11.2	4.3	9.2
Toronto-London	82.4	11.3	5.2	1.2
Toronto-Sudbury	55.2	5.7	22.5	16.6
Average	70.4	6.7	12.4	10.4

Notes: see Table 3.2 for actual volumes.

For demand modelling of intercity travel, access, egress, and process time for a trip should be added to any analysis that includes time factors. In the Corridor the fastest mode, CTOL, does not enjoy a marked superiority on some of the links because of the short haul nature of the markets. When the total trip time is examined in the light of the higher trip costs of CTOL it becomes evident why, without an extreme passenger value of time, CTOL does not dominate these markets.

For the [✓]SOMPS project, Transport Canada had prepared 1976 estimates of population and disposable income for each city, as well as projections for 1986 and 1991. Population and income figures are used in demand model calculations.

In the Canadian context, intercity demand calculations must consider the impact of language differences between cities on trip generation. Language pairing indices were derived as discussed in Appendix F.

3.2 Scenarios

In order to examine possible opportunities for energy conservation in the medium term to 1991 a series of scenarios of future system technology and management conditions were developed. The scenarios examine impacts of various attempts to control the demand-supply interaction. By reducing the demand for transportation, energy savings can be realized.

General assumptions that apply to all scenarios are noted. It is assumed that transportation costs, except energy costs, remain constant in real terms. With the exception of technology and supply factor changes explicitly identified as a part of scenarios discussed here, all other determinants of travel are assumed to have constant effect.

Socioeconomic factors (populations, incomes, language factors) are constant across scenarios, but may change by years. In all scenarios, technological changes in energy economy of vehicles are accounted for in energy consumption calculations. Additionally, in selected scenarios, the effect of fuel cost savings are taken into account in demand calculations.

Descriptions of the seven scenarios follow. The results, analysis and implications of the scenarios are discussed in Chapters 4 and 5.

3.3 Base Scenario

Base scenario provides a base-line so that the results of the

other scenarios could be compared against it. Base scenario level of service variables remain relatively constant from 1976 through 1991. In particular, trip costs borne by the traveller remain constant. Load factors are allowed to rise to maximums of 70% for bus, 60% for rail, and 60% for CTOL.* Auto load factors are held constant. No load factors are allowed to fall below 1976 levels.

3.4 Scenario A

Scenario A is similar to Base scenario except traveller trip costs change to reflect an annual 3% increase in energy costs, as forecast by the Department of Energy, Mines, and Resources²⁹. In effect, improvements in fuel economy of vehicles are lost to the travellers' cost of travel. This could show an energy consumption reduction due to travellers shifting to more efficient modes.

3.5 Scenario B

Scenario B retains the constant level of service characteristics of 1976, as in Base scenario, except rail service improvements to 100 mph line-haul speeds on all links except Toronto-Sudbury are introduced. Fare levels remain constant. This scenario shows possible energy consumption savings due to a modal shift to rail because of higher speed service. Toronto-Sudbury is not included as the low volume of O-D travellers did not warrant any great infrastructure changes to institute a higher speed service.

* with a few exceptions noted in the section on demand inputs.

3.6 Scenario C

Scenario C combines the cost changes of scenario A with the rail improvements of scenario B. This is more realistic than scenario B except there is no increase in rail fare beyond the basic annual 3% energy cost increase. It was expected that scenario C would show even more shifting to the rail mode. Toronto-Sudbury is again not included.

3.7 Scenario A'

Scenario A' is similar to scenario A except that in addition to an annual energy cost increase of 3% the energy cost effects of technological changes in vehicle fuel economy accrue to the traveller. This scenario was intended to examine the possibility that improvements in fuel economy, particularly in automobiles, combined with increases in the price of energy (both desirable to reduce total energy consumption) could actually lead to such an increase in travel that total energy consumption increased.

3.8 Scenario B'

Scenario B' is the same as scenario B except rail trip costs are increased by a 50% increase in the line-haul fare to more realistically assess the impact of an improved rail service. Toronto-Sudbury is not included.

3.9 Scenario C'

Scenario C' is the same as scenario C except CTOL trip costs are increased by a 20% increase in the line-haul fare. This is to encourage shifts away from the highest energy consuming mode, CTOL. Toronto-Sudbury is included but without any rail speed changes from scenario A.

Chapter 4

Calculation Process4.1 The Demand Model

The demand model is a quasi-direct, quasi-abstract model developed by Monsod^{30,31} and modified and calibrated by Wills³² for the Windsor-Quebec City corridor.

The mathematical description of the demand model is given below:

$$T_{ijm} = T_{ij} \cdot S_{ijm} \quad (1)$$

$$S_{ijm} = U_{ijm} / \sum_n U_{ijn} \quad (2)$$

$$U_{ijn} = \alpha_n \prod_k C_{ijnk}^{\alpha_k} \quad (3)$$

$$T_{ij} = \beta_0 (P_i P_j)^{\beta_1} Y_{ij}^{\beta_2} L_{ij}^{\beta_3} (\sum_n U_{ijn})^{\beta_4} \quad (4)$$

where

T_{ij} is total travel between cities i and j

T_{ijm} is travel by mode m

S_{ijm} is share of mode m

U_{ijm} is the level of service of mode m

C_{ijnk} is a "cost" term of mode n, "costs" are fare, trip time, and departure frequency

P_i, P_j are total populations of cities i and j

Y_{ij} is the average annual per capita disposable income

L_{ij} is the language pairing index

α_n : automobile 1.0

CTOL 34.120

rail 60.039

bus 24.953

α_k : fare -0.942, cents, door-to-door

time -1.447, minutes, door-to-door

frequency 0.538, departures per week, auto = 9999

$\beta_0 = 8.9923$

$\beta_1 = 0.7674$

$\beta_2 = 0.5611$

$\beta_3 = 0.2311$

$\beta_4 = 0.5510$

Consider the own-elasticity of travel by mode m , T_{ijm} , with respect to cost variable C_{ijmk} :

$$T_{ijm} = T_{ij} \cdot S_{ijm} = T_{ij} \cdot U_{ijm} / (\sum_{\ell} U_{ij\ell}) \quad (5)$$

$$\log T_{ijm} = \log T_{ij} + \log U_{ijm} - \log (\sum_{\ell} U_{ij\ell}) \quad (6)$$

$$\text{then } \frac{\delta T_{ijm}}{\delta C_{ijmk}} = \frac{T_{ijm}}{T_{ij}} \frac{\delta T_{ij}}{\delta C_{ijmk}} + \frac{T_{ijm}}{U_{ijm}} \frac{\delta U_{ijm}}{\delta C_{ijmk}} - \frac{T_{ijm}}{\sum_{\ell} U_{ij\ell}} \frac{\delta (\sum_{\ell} U_{ij\ell})}{\delta C_{ijmk}} \quad (7)$$

$$\text{and if } R = \beta_0 (P_i P_j)^{\beta_1} Y_{ij}^{\beta_2} L_{ij}^{\beta_3}$$

$$\text{we get } \frac{\delta T_{ijm}}{\delta C_{ijmk}} = R \alpha_k C_{ijmk}^{-1} U_{ijm} (\sum_{\ell} U_{ij\ell})^{\beta_4-1} [1 + U_{ijm} (\sum_{\ell} U_{ij\ell})^{-1} (\beta_4 - 1)] \quad (8)$$

For cross-elasticity of T_{ijm} with respect to cost C_{ijnk} :

$$\text{we get } \frac{\delta T_{ijm}}{\delta C_{ijnk}} = R \alpha_k C_{ijnk}^{-1} U_{ijn} \left(\sum_{\ell} U_{ij\ell} \right)^{\beta_4 - 1} [U_{ijm} \left(\sum_{\ell} U_{ij\ell} \right)^{-1} (\beta_4 - 1)] \quad (9)$$

The terms U_{ijm} , U_{ijn} or $\sum_{\ell} U_{ij\ell}$ appear often in equations 8 and 9.

If we consider elasticity of any cost term, the elasticity will be greatest for the mode with the largest α_n term. This is rail, with α_n of 60.039. CTOL has α_n of 34.120 and bus, 24.953. Automobile has an α_n value of only 1.0. (As mentioned later in discussion of demand model results, rail may be over-sensitive)

4.2 The Demand Model Program

A computer program was written to do the calculations required by the demand model. A commented listing of the program and a list of variables and their meaning is in Appendix C. A conceptual flowchart of the calculation process is shown in Figure 4.1.

The demand model program follows a two-step process. One: the base year level of service and socioeconomic inputs are processed. Ratios of the results of the calculations are made with the base year travel data (total travel and modal splits). Two: the forecast year level of service and socioeconomic inputs are processed. The outputs of the calculations on the forecast year data are multiplied by the ratios determined for the base year. This yields the forecast year projections of total travel and modal splits.

The program has been written to print the total user cost and total user trip time as well.

Figure 4.1

Conceptual Flowchart of Demand Modeling Program

This is the simplest way of using the demand model program. However, there are some things that may be added to the calculation process to increase the usefulness of the outputs and to better simulate the future system. The vehicle sizes can be input and the load factors calculated using volume and frequency data. This is just a convenience for the user of the program in eliminating some simple calculations. If the forecast year frequencies are too small then the load factors output will be too high. The user would then enter new frequencies to reduce the load factor.

Frequencies are part of the level of service of the system and increasing the frequencies will generate additional demand. Fortunately, there is a diminishing return and the added trips will not generate more traffic than the amount of increase of frequency. Load factors will fall. The frequency changes can be repeated until satisfactory load factors are reached.

This iterative process, which is a way of simulating the supply response of the system, is easily modelled by the computer. The user can input at the start of the process target load factors, or target ranges of load factors, and the program will calculate successive projections until the load factors meet the targets.

With this process changes in vehicle size, due perhaps to technological changes, can also be handled and the desired load factors obtained.

The load factor control does not work for private automobile. The demand model requires the automobile frequency to be a large constant number (that is, large in comparison to public mode frequencies). In the work reported here, automobile frequencies were set at 9999999 departures per year. Load factors calculated from this frequency were absurd. The allowable range of automobile load factors was set to be 0 to 200%, which would not change the 9999999 figure. It was assumed the actual load factors were constant through all scenarios and years for energy calculations. This is not unrealistic since automobile levels of service can be expected to remain constant in the future. Certainly availability and ease of departure time choice, as simulated by the number of departures per year, will not likely change much.

The demand model formulation expressed frequencies as departures per week. Annual demand and energy figures are much more useful than weekly figures. In this thesis annual frequencies were used. This will not invalidate the model because it is used to calculate ratios of demand; as long as parameters are all expressed consistently the ratios will be unchanged. Auto frequency was set at 9999999 instead of 519948 (9999×52) because the lower auto frequency is close enough to the higher-frequency public modes that unacceptable decreases in auto traffic occur.

4.3 Demand Model Input Data

For an energy analysis load factor data is necessary. Therefore load factors were controlled in all scenarios. The 1976 load factors were known, and served as a starting point for load factors for future years. In the forecast years load factors were allowed to rise to 60% for CTOL, 60% for rail, and 70% for bus, except where these load factors were exceeded in 1976. Where the 1976 load factors were slightly larger (2%) than the limits above, the above limits stood. Where load factors were greatly over the above limits the 1976 actual load factors became the maximum. This occurs in CTOL for Montreal-Toronto and Toronto-Ottawa/Hull. Toronto-Sudbury CTOL 1976 load factor was 67%. The new maximum allowed was set to 60% as the lower load factor

seemed more reasonable for such a route.

Any rise in load factors does not directly affect demand because load factors are not involved in the demand equation. Once maximum load factors are met, then frequency is increased and the frequency increase does affect travel demand.

Allowing load factors to rise this way is a rough simulation of carriers' response to increased demand. Load factors are allowed to rise to a point the carriers seem to feel is successful. Rises beyond the reasonable point are not allowed because this would indicate overcrowding on trips made during peak periods, a situation carriers would try to avoid.

The travel demand figures used in this thesis are for O-D demand only. In reality, through travellers are also carried and service characteristics such as vehicle size and departures are set to accommodate the total demand. For O-D demand modelling purposes, departures, which are an input to the demand model, are set to correspond to the 1976 O-D demand by mode and mode load factor.*

Vehicle sizes, while not direct inputs to the demand model, are used in calculation of load factors which are used to adjust departure frequencies when necessary. Departure frequencies are input to the demand model, therefore the choice of vehicle size can be important.

* Automobile departures are handled differently, as noted in the previous section.

LRC rail vehicles come in various configurations but are likely to be approximately 76 to 80 seats per coach. 76 seat coaches were used here, giving train sizes of 152, 228, 304, 380 and 456 seats. In running the demand program the expected needed train size was input. Subject to load factor control, frequencies would be adjusted to accommodate demand. If the resulting frequencies were too great a larger train size was substituted and the program re-run.

Intercity buses were assumed to remain constant in capacity - 46 seats per bus. Automobiles were also assumed to be of constant capacity at 5 seats per auto.

Air vehicle sizes varied from link to link. Air Canada's 1984 projected service vehicle sizes for all links except Toronto-Sudbury were obtained.¹⁷ These were assumed to be representative of service to 1991 and included new types such as either Boeing 767 or Airbus A310 with 218 seats per aircraft. On links where the projected service was a mix of types weighted average vehicle sizes were used for demand calculations. (This assumes frequency changes would not affect the mix of types flown on that link)

For base year demand calculations (and energy calculations) a possible approach was to find the actual seats and aircraft types provided. In this thesis however, this approach was judged unnecessarily detailed. A previous study used B727-200 (144 seats) as representative of the 1976 aircraft mix and configuration.⁷ In some links though, the Air Canada forecasts indicated future service using DC-9-32 aircraft with 102 seats. If 144 seat B727 aircraft are used for 1976 Base demand

calculations and future years used the smaller aircraft the frequencies would increase unrealistically. Therefore on links with a forecast of smaller aircraft than the B727, the forecast aircraft was used for 1976 Base as well as for future years. The aircraft types are constant for all scenarios of a given link and year.

Montreal-Quebec City was assigned DC-9-32 aircraft for 1976 and B727-200 for future years to restrain an excessive growth in CTOL travel demand. This too is a rough simulation of carrier response to demand. When traffic increases larger aircraft are usually brought in.

Trip costs, times, and distances were obtained from the Canpass-3 data base. The information in the Canpass system was based on available sources. This involved some arbitrary assumptions in the access link calculations and schedule interpretation, especially in the bus mode³³.

The access link was assumed to be from community centroid to the modal terminal. The link length was calculated from the latitude and longitude of the community centroid and the terminal. The link travel time is computed from the link distance and a function based on perceived auto operating characteristics. The link travel fare is computed using a cost function based on the link distance and perceived private and commercial auto operating costs³⁴.

The Canpass access distance was not used in this thesis, but access costs and times from Canpass were used.

Errors due to assumptions in the Canpass data should be systematic and not compromise the validity of the data in a study which aggregates results over six or seven links.

Scenarios Base, B, and B' use 1976 costs for all years except for B' rail. Scenarios A, C, and C' use cost data adjusted for energy cost inflation. These appear in the cost tables as costs for 1986 and 1991. Scenario A' uses a different cost adjustment from scenario A. Methods for calculating energy cost adjustments for scenarios A, C, A', and C' appear in Appendix G.

Trip times were taken from Canpass-3 data and used unchanged for all scenarios, except rail in B, C, B', and C'. For those scenarios the rail trip times were altered to reflect an average line-haul speed of 100 miles per hour.

4.4 Toronto-London-Windsor Subsystem

Most of the links in this study are point-to-point and can be considered individually. Toronto-London is on the Toronto-Windsor route. For all modes except rail, this is of little consequence. For rail,

however, it is much more realistic to consider the Toronto-Windsor and Toronto-London services as a system.

The service would consist of trains serving Toronto-London only and trains stopping in London, perhaps changing consist there, and then continuing on to Windsor. Toronto-London travellers would be evenly split amongst all the trains to London, and Toronto-Windsor travellers would travel only on those trains that run through London. The demand program was used to calculate travel for each city pair separately, and rail travellers were assigned to trains in combination. For these links, the rail frequencies were set to a certain number of trains per day so that the correct number of through and London-only trains were obtained. The train sizes and load factors were calculated externally but were set to be reasonable for the service.

4.5 Demand Model Results

The results of the demand model calculations are presented in Table 4.1. These numbers are not the results obtained directly from the program. Unfortunately, it appears that the total demand part of the model is overly sensitive. This led to unacceptable cross-elasticity effects. For example, an increase in rail level of service, such as occurs in scenario B, would lead the demand model to forecast reasonable modal splits, but an unreasonable increase in travel demand. The excessive demand increase would give growth in the actual volume of auto travel even though auto modal split had declined.

Table 4.1

Total Travel System Without Sudbury
(Annual Trips)

Year	Scenario	Total Trips	Automobile	CTOL	Rail	Bus
1976	Base	16933000	12004000	1735000	1148000	2047000
1986	Base	23107000	15897000	2601000	1581000	3028000
	A	22504000	15005000	2680000	1663000	3167000
	B	23547000	15489000	2462000	2638000	2958000
	C	23059000	14652000	2531000	2767000	3109000
	A'	22866000	15543000	2566000	1675000	3102000
	B'	23271000	15778000	2623000	1802000	3014000
	C'	22930000	14753000	2172000	2870000	3135000
1991	Base	27253000	18175000	3236000	1973000	3869000
	A	26239000	16630000	3382000	2128000	4099000
	B	28047000	17757000	3063000	3425000	3802000
	C	27044000	16196000	3157000	3679000	4012000
	A'	27450000	17810000	3043000	2199000	4398000
	B'	27541000	18084000	3263000	2332000	3862000
	C'	26866000	16306000	2731000	3785000	4044000

To eliminate this problem, the total demand predicted was reduced to obtain reasonable volumes on each mode. The model-predicted modal splits were retained. The adjusted volumes of each scenario were checked against other scenario results to ensure reasonableness.

This procedure is not unreasonable and is in accordance with the state-of-the-art of demand modelling. In all demand models that the author knows of there is always a need to constrain the model's coefficients. In this case no constraints were specified.

In the use of the model, for all links except Montreal-Toronto (which already had quite high rail speeds), due to substantial upgrading of rail's speed and other service parameters, it became evident that the model's output had to be systematically constrained. The load factor/frequency interaction could also increase this effect.

As the model is of semi-abstract form it is not surprising that modal splits could be reasonable and demand projections excessive.

4.6 Energy Calculations

The energy model is conceptually simple. Transportation system outputs, travellers and modal splits are multiplied by appropriate energy intensities to yield energy consumption figures. The calculation in this study was done by a computer program which simply reads in numbers for demand, distances, modal splits, and energy consumption rates; multiplies them; and prints out the results. A more detailed description of the program appears in Appendix D.

4.7 Energy Consumption Inputs

Direct energy consumption, the energy actually used for propulsion, was discussed in Chapter 2. Indirect energy was defined in Chapter 2. The major components of indirect energy are: energy to produce fuel, vehicle construction energy, vehicle maintenance energy, infrastructure construction energy, and infrastructure operation and maintenance energy.

The energy required to produce fuel is the energy used in providing the fuel used to the vehicle. This includes exploration and refining energy. It would be necessary to know how much energy is used in this component in a study to relate energy demand to production or to reserves, but it could be argued that this component is unnecessary in a study such as this since energy to produce fuel is an unavoidable energy expenditure. However, there are differences in the proportion of energy to produce fuel to direct fuel consumed. To provide gasoline for automobiles requires 19.5% of the direct energy provided (i.e., 119.5% of direct energy is used for the two items). Diesel fuel, on the other hand, is easier, or at least more efficient, to produce. The energy to produce diesel fuel is 12.6% of the direct consumption. A shift of travel from gasoline to diesel fueled modes would lead to a saving of 6.9% of the direct fuel consumed. Because some modes are gasoline fueled, and some are diesel fueled, it is necessary to include the energy to produce fuel component.

The vehicle construction energy is the sum of the energy required to build and deliver a vehicle, less any salvage of energy when the vehicle is retired, amortized over the life of the vehicle.

Vehicle maintenance energy is the energy to keep the vehicle serviceable, to clean it, to supply lubrication, the energy in the lubrication itself, and energy for administration and support of the vehicle and the service.

Infrastructure construction energy is similar to vehicle construction energy. It is the sum of the energy to build a facility, less any energy salvage on retirement, amortized over the life of the facility. This component of indirect energy could be quite high, depending on the design of the infrastructure and its expected life or service. In this study, although infrastructure construction energy consumption figures are reported, they are not used in calculations.* It was assumed that infrastructure is essentially in place, and any expenditures on construction are likely to be small and covered by the operation and maintenance component.

Infrastructure operation and maintenance energy is broken down into energy for terminals and energy for guideways. Presumably, the energy consumed could be broken down into a fixed portion, relating to such

* Infrastructure has to be built for the 100 mph rail services. The energy required for this is 238,100 Btu per train mile.⁴⁵ It is included in energy calculations for scenarios B, C, B', C'.

things as snow clearance and deterioration due to age, and a variable portion dependant on usage. Practically though, the energy consumed is presented solely as a variable term, dependant on usage.

The derivation of the figures for these indirect energy consumption components is described in Chapter 2 and by Fels and IBI Group^{8,20}.

The access/egress portion of the trip was found to be a significant part of the total energy consumption. Data on urban transport energy consumption is found in many of the same reports that report intercity consumption. A modal split for access modes was harder to find. A CTC study and studies by Transport Canada reported figures on access/egress for Quebec City, Montreal, Ottawa/Hull, and Toronto^{35,36,37}.

For CTOL, rail and intercity bus modes, basic data from the CTC study was used to obtain access times and access mode choice. Each city was broken down into a number of zones. These zones are shown on small scale maps in the CTC report.

Distances from each zone to each intercity mode terminal were scaled off of appropriate detailed maps. It was assumed that all access modes travelled the same distance to the terminals from each zone. For each intercity mode, tables from the CTC study were consulted to find the geographic distribution and zonal access time. Using the distances and times from each zone, average zonal access speeds were calculated. The average zonal access speeds were multiplied by the

fraction of travellers originating in that zone, for that access mode, to give a city weighted average access speed. Weighted average access times and distances were also found. The access modal split for each terminal was also found from the CTC and Transport Canada data.

Windsor, London and Sudbury were not considered by the CTC study. Since the amount of traffic to these cities is small in comparison to the rest of the system, an assumption that all access was by automobile is not likely to lead to excessive error. Average access times and distances were extracted by calculations on data in the Canpass-3 data. Speeds were calculated from the times and distances.

For automobile as an intercity mode, access is assumed to be by automobile. The access portion of the energy consumption is covered by the urban portion of the automobile intercity trips. Derivation of automobile urban/rural breakdown is discussed in Appendix E.

The choice of terminal access modes is shown in Table 4.2.

4.8 Results of Energy Calculations

The program calculates energy one link at a time, one scenario at a time. The volume of output precludes including it here. Sample outputs are shown in Appendix B.

Table 4.3 shows total energy consumption for each scenario and mode. See Chapter 5 for a discussion of these results.

Table 4.2

Choice of Terminal Access Modes

Intercity Mode	Access Mode	Quebec City %	Montreal %	Ottawa/Hull %	Toronto %
CTOL	Automobile	49.3	49.9	49.8	53.8
	Bus	1.0	6.8	1.3	6.9
	Metro	-	0.2	-	2.2
	Taxi/Limo.	48.0	42.2	48.2	36.3
Rail	Automobile	33.5	24.0	47.7	31.1
	Bus	8.5	9.6	31.8	5.8
	Metro	-	11.2	-	28.1
	Taxi/Limo.	46.9	34.6	38.6	26.9
Bus	Automobile	20.7	14.6	34.2	26.2
	Bus	20.6	19.7	21.8	14.8
	Metro	-	15.4	-	26.3
	Taxi/Limo.	43.7	25.4	26.4	22.5
STOL	Automobile	N.A.	42.0	42.0	35.1
	Bus	N.A.	0	0	5.2
	Metro	N.A.	0	0	14.3
	Taxi/Limo.	N.A.	15.5	15.5	45.3
	Stolmobile	N.A.	41.0	41.0	N.A.

Notes: Breakdowns may not total 100%, the balance is primarily walking access.
 Stolmobile is a van-type vehicle used in the air transit demonstration.
 N.A. means not available.

Because access data was not available, Windsor, London, and Sudbury passengers were assumed to use automobiles for access.

Sources: References 35, 36.

Table 4.3

Total Energy Consumption (Btu) System Without Sudbury

Year	Scenario	All Modes ($\times 10^{13}$)	CTOL ($\times 10^{12}$)	Rail ($\times 10^{12}$)	Bus ($\times 10^{11}$)	Auto ($\times 10^{13}$)
1976	Base	2.01595	4.3061	1.15505	6.6544	1.4033
1986	Base	2.35713	5.7219	0.98329	7.8814	1.6078
	A	2.26092	5.6827	1.02255	8.1297	1.5091
	B	2.38662	5.6452	1.83956	7.8241	1.5599
	C	2.29741	5.6010	1.89798	8.0414	1.4671
	A'	2.32833	5.5955	1.02860	8.0115	1.5858
	B'	2.40192	5.7837	1.30893	7.8659	1.6140
	C'	2.28244	5.0644	1.97898	8.0300	1.4978
1991	Base	2.41917	6.8323	1.16071	8.5072	1.5348
	A	2.31918	7.1021	1.25911	8.9255	1.3938
	B	2.50014	6.7376	2.34501	8.4476	1.5074
	C	2.34446	6.6484	2.42952	8.7466	1.3489
	A'	2.37403	6.4202	1.27702	9.5012	1.5093
	B'	2.47069	6.9171	1.64885	8.5399	1.5287
	C'	2.32955	6.1538	2.50879	8.8188	1.3751

Chapter 5

Results

5.1 Demand Results

The total travel demand under various scenarios was presented in Table 4.1. Changes in travel demand for the system are shown in Table 5.1. The system modal splits are shown in Table 5.2.

Figure 5.1 shows, for the Base scenario, a graph of travel demand with average income and total population. Demand increases by 61% from 1976 to 1991. Figure 5.2 shows total travel, for each scenario in 1991 and 1976 Base. Modal shares are also shown.

In the Base scenarios, the automobile share declines through 1986 and 1991 from 1976 because as carriers react to increasing travel demand due to population growth the public modes' levels of service improve while automobile's level of service remains constant.

In scenario A automobile volume and modal share decline with respect to Base scenario. Fuel prices hit automobile travellers the hardest. Rail picks up the most new traffic followed by bus and CTOL. Total travel is down because some auto travellers do not travel at all.

Scenario B total demand increases with respect to Base scenario. Improved rail service generates new travel and picks up passengers from other modes as well. CTOL suffers the largest loss followed by

Table 5.1

Changes in Travel Demand, System Without Sudbury

(%)

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
1986	Base	36.5	49.9	37.7	47.9	32.4
	A	-2.6	3.0	5.2	4.6	-5.6
	B	1.9	-5.3	66.9	-2.3	-2.6
	C	-0.2	-2.7	75.0	2.7	-7.8
	A'	-1.0	-1.3	5.9	2.4	-2.2
	B'	0.7	-0.8	14.0	-0.5	-0.7
	C'	-0.8	-16.5	81.5	3.5	-7.2
1991	Base	60.9	86.5	71.9	89.1	51.4
	A	-3.7	4.5	7.9	5.9	-8.5
	B	2.9	-5.3	73.6	-1.7	-2.3
	C	-0.8	-2.4	86.5	3.7	-10.9
	A'	0.7	-6.0	11.5	13.7	-2.0
	B'	1.1	0.8	18.2	-0.2	-0.5
	C'	-1.4	-15.6	91.8	4.5	-10.3

Base scenarios relative to 1976 base

Other scenarios relative to own-year base

Table 5.2

System Modal Splits Without Sudbury

(%)

Year	Scenario	CTOL	Rail	Bus	Auto
1976	Base	10.2	6.8	12.1	70.9
1986	Base	11.3	6.8	13.1	68.8
	A	11.9	7.4	14.1	66.6
	B	10.5	11.2	12.6	65.8
	C	11.0	12.0	13.5	63.5
	A'	11.2	7.3	13.6	67.9
	B'	11.3	7.8	13.0	68.0
	C'	9.5	12.5	13.7	64.3
1991	Base	11.9	7.2	14.2	66.7
	A	12.9	8.1	15.6	63.4
	B	10.9	12.2	13.6	63.3
	C	11.7	13.6	14.8	59.9
	A'	11.1	8.0	16.0	64.9
	B'	11.8	8.5	14.0	65.7
	C'	10.2	14.1	15.1	60.7

Figure 5.1

Graph of Total Travel, Average Income, and Population,
1976, 1986, and 1991

Figure 5.2

Comparison of Travel and Direct Energy Consumption
by Scenario and Mode, 1976 and 1991

auto and bus, with roughly equal losses. Since most of the travel is by automobile, it is auto that loses the most travellers.

Scenario C demand decreases because the impact of fuel price penalties is larger than any rail demand generation. Rail's share increases further than in scenario B by shifts from CTOL, auto, and bus. Bus does not decline as much as in scenario B but does not grow as much as in scenario A because of shifts to rail.

Scenario A' demand decreases slightly in 1986 because the influence of fuel price penalties is greater than improvements in fuel economy. In 1991, the fuel price penalties are smaller than the fuel economy improvements in rail and bus access. CTOL and automobile fuel price increases are almost equalled by fuel economy improvements leaving relatively small increases of 1991 trip costs over 1976 trip costs; and usually decreases in 1991 trip costs over 1986 trip costs. Bus and rail benefit the most from the fuel price/ fuel economy adjustments while CTOL and automobile are not severely penalized.

Scenario B' demand increases slightly because of demand generated by improved rail speeds. Modal shifts away from auto and bus are smaller than in scenario B, while CTOL increases slightly due to shifts away from rail because of the higher rail fare. Rail demand grows with respect to Base scenario but the increase is far smaller than in scenario B.

Scenario C' demand decreases because CTOL volume declines greatly because of fare increases. Some shift to auto and bus occurs. Bus doesn't increase as much as in scenario A but more than in scenario C. Auto declines less than in scenario C but more than in scenario A. Some auto and bus travellers are shifting to rail while some CTOL travellers are shifting to rail, bus, and auto. Rail enjoys the largest modal shift to it of any of the scenarios, but generated demand does not equal the loss experienced by CTOL.

5.2 Energy Results

Total system energy consumption was presented in Table 4.3. Total direct energy consumption is in Table 5.3. (System with Sudbury results are not included here as the differences between with and without Sudbury results are small.)

Figure 5.3 shows a comparison between the growth in travel demand and direct energy consumption, for the Base scenario. Note how little the energy consumption grows compared to travel growth. The lower part of Figure 5.2 shows direct energy for 1976 and 1991. Note the smaller difference in height between the energy lines from 1976 to 1991 compared to the travel lines above. Also note the small differences in height of the energy lines amongst the 1991 scenarios.

Table 5.3

Total Direct Energy Consumption System Without Sudbury

(Btu)

Year	Scenario	All Modes ($\times 10^{13}$)	CTOL ($\times 10^{12}$)	Rail ($\times 10^{11}$)	Bus ($\times 10^{11}$)	Auto ($\times 10^{13}$)
1976	Base	1.37387	3.15230	7.66420	4.75313	0.93447
1986	Base	1.55179	4.12261	5.53977	5.53720	1.02875
	A	1.48701	4.06692	5.76826	5.70524	0.96558
	B	1.57653	4.09470	11.39790	5.50464	0.99803
	C	1.51672	4.04041	11.74380	5.64739	0.93878
	A'	1.53130	4.02515	5.79165	5.62507	1.01462
	B'	1.58691	4.16882	8.20020	5.52752	1.03275
	C'	1.50582	3.68759	12.23490	5.63485	0.95838
1991	Base	1.53349	4.88724	6.42761	5.78285	0.92267
	A	1.47645	5.07574	7.02415	6.06055	0.83802
	B	1.59349	4.85708	14.40340	5.74935	0.90624
	C	1.49442	4.75386	14.84520	5.96390	0.81094
	A'	1.50176	4.59271	7.07021	6.44897	0.90730
	B'	1.57501	4.95177	10.26960	5.80864	0.91905
	C'	1.48565	4.45620	15.33880	5.99034	0.82675

Figure 5.3

Graph of Direct Energy Consumption and
Total Travel
1976, 1986, and 1991

The 1986 Base total travel is 36.5% greater than 1976 base, while total energy consumption is only 16.9% greater. Total direct energy consumption grows 13.0% from 1976 to 1986.

The 1991 Base total travel is 60.9% greater than 1976. Total energy consumed in 1991 is however only 20.0% greater than in 1976. Total direct energy is 11.6% greater than in 1976.

Total direct energy consumption in 1991 Base is less than in 1986 Base even though traffic is 17.9% greater in 1991 than in 1986. Automobile total direct energy consumption in 1991 is less than even 1976. The other modes' consumption rises, but automobile improvements have a greater effect on the total.

The relatively small increases in consumption from 1976 to 1986 Base and 1991 Base are due to vehicle fuel economy improvements and increases in public transportation load factors. No price or service changes, except improvements in service to accommodate travel growth when load factors warrant, are imposed in the base scenarios.

Savings in energy due to price and service changes of scenarios other than Base are relatively small. Except for high speed rail,

all scenarios of a given year use the same vehicles. Automobile dominates the system travel. Shifts away from auto and load factor improvements in the public modes are not great enough to have a large impact on total energy consumption.

Scenario A, both in 1986 and 1991 forecasts the minimum amount of energy use, but total energy used in A is only 4.1% less than total energy used in Base. Scenario A total direct energy is 4.2% less than Base total direct energy in 1986 and 3.7% less than Base total direct energy in 1991.

Relative rankings of system energy consumption are shown in Table 5.4. The 1986 and 1991 rankings only change amongst Base, B and B'.

The scenario with the largest total energy consumption in 1986, B', consumes 1.4% more energy than 1986 Base and 18.6% more energy than 1976 Base. Volume of 1986 B' is 0.7% greater than 1986 Base and 37.4% greater than 1976 Base.

The scenario with the largest total energy consumption in 1991, B, consumes 3.3% more energy than 1991 Base and 24.0% more energy than 1976 Base. Volume of 1991 B is 2.9% greater than 1991 Base and 65.6% greater than 1976 Base.

The most efficient scenario, C, uses 16.5% less total energy per effective passenger mile in 1986 than 1976, and 27.4% less total energy per passenger mile in 1991 than 1976.

Table 5.4

System Energy Consumption

Scenarios Ranked by Increasing Consumption: System Without Sudbury

Total Energy		Direct Energy		Indirect Energy		
1986	1991	1986	1991	1986	1991	
A	A	A	A	A	A	Least.
C'	C'	C'	C'	C'	C'	
C	C	C	C	C	C	
A'	A'	A'	A'	A'	A'	
Base	Base	Base	Base	Base	Base	
B	B'	B	B'	B	B'	
B'	B	B'	B	B'	B	Most.

Relative rankings of system energy efficiency are shown in Table 5.5. These rankings are more confused than those for energy consumption because of small differences between efficiencies of each scenario. In general, all scenarios use the same vehicles, so similarities are not surprising. Differences are due to different load factors and high speed rail used in some scenarios.

5.3 Other Results

Average user trip time is almost constant. Trip time is improved in high speed rail scenarios (B, B', C, C'), even in C' where significant shifts away from CTOL occur.

Average user trip cost is highest for the least energy consuming or most efficient scenarios (A, C, C'). The high price of rail in scenario B' does not have a large impact on average user trip cost because the fares discourage much travel on rail.

5.4 Comparison With Other Work

A recent study by the Bureau of Management Consulting²⁹, developed one scenario similar to the Base scenario in this thesis. A comparison table of BMC results for their scenario B in 1990 and Base scenario 1991 is Table 5.6. BMC scenario B used vehicles with forecast fuel economy changes, no load factor changes, and no fuel price increases;

C

Table 5.5

System Energy Efficiency

Scenarios Ranked by Decreasing Efficiency, System Without Sudbury

Total Energy		Direct Energy	
1986	1991	1986	1991
C	C	C	A' Most.
C'	A'	C	C
A	C'	A	C'
B	A	B	A
A'	Base	A'	Base
Base	B	Base	B
B'	B'	B'	B' Least.

Table 5.6

Comparison With BMC Results

	Auto		Bus		Rail		CTDL		All Modes	
	BMC	Thesis	BMC	Thesis	BMC	Thesis	BMC	Thesis	BMC	Thesis
Travel Demand, Millions of Effective Passenger Miles	2301	2720	558	572	375	380	918	847	4152	4519
Direct Energy, Billions of Btu's	6262	9227	556	578	725	643	5983	4887	13526	15335
Direct Energy, Btu/Effective Passenger Mile	2721	3392	996	1010	1933	1690	6517	5772	3258	3394
Total or Avoidable Energy, Billions of Btu's	10201	15348	848	851	944	1161	7568	6832	19561	24192
Total or Avoidable Energy, Btu/Effective Passenger Mile	4433	5643	1520	1487	2517	3052	8244	8069	4711	5354

BMC results are their scenario B, 1990, for the corridor with some different links than are used in this thesis. Energy rates were calculated from BMC results.

Thesis results are 1991 base scenario, system without Sudbury.

BMC: Reference 39.

this is similar to Base scenario in this thesis. There are some differences, notably a slightly different network or system. BMC's "avoidable energy" is the same as this thesis' "total energy" less infrastructure operation, maintenance and construction.

In spite of differences in approach, calculation procedure and system the results are similar between the two studies. The greatest differences are between the automobile consumption rates; and differences are larger in total or avoidable energy in all modes.

There are several differences between this thesis and the BMC study. The BMC scenario B has load factors constant at 1977 levels while this thesis' Base scenario allows load factors to increase. BMC travel demand figures are not arrived at by any demand modelling exercise but are projected to grow in accordance with general economic and population growth. Demand growth on all links is the same. Generated demand from changes in level of service is not included. Improvements in vehicle fuel economy are projected by constant factors, not directly reflecting forecast technical changes. The BMC study used constant factors across all links to represent the access/egress portion of the energy consumption. Also the urban portion of automobile and bus fuel consumption was constant across all links.

The approach used in this thesis is superior to that of the BMC. In this thesis travel demand is calculated by a demand model instead of extrapolation as used in the BMC work. Use of a model is better

because it uses determinants of travel growth (population, income, etc) instead of looking solely at past traffic.

The modal splits in the thesis are arrived at by calculations by the demand model. They are not an accident of extrapolations made on a mode by mode basis.

The access and egress energy was calculated specifically, not just taken as a constant proportion of the line-haul energy.

Travel projections are made on a link specific basis. In the BMC work, projections of rates of growth are constant accross all links.

All of these should make the thesis more indicative of the merit of any particular energy conservation scheme.

The relative agreement between the results of the two studies suggest that further study emphasis on which data are more representative of the real energy consumption in the system would be useful.

Chapter 6

Summary, Conclusions, and Extensions

6.1 Summary

The purpose of this thesis was to collect data and show a method for calculating energy impacts of technological change and demand management in an intercity, multimodal passenger transport system.

Data on the level of service and socioeconomic characteristics of the Quebec City-Windsor corridor were collected. Scenarios were developed demonstrating possible future system level of service characteristics, and corresponding travel demand figures calculated using a demand model. Energy consumption data, including direct and indirect, access/egress and line-haul portions, for all modes, for the present and forecast for the future was collected. The energy consumption by the system under each scenario was calculated using the demand and energy figures.

6.2 Conclusions

In order of decreasing energy efficiency the modes can be ranked: bus, rail, automobile, and CTOL. This ranking holds for all scenarios, all years, for both direct and total energy consumption.

Total direct energy consumption improvements are greater than the total energy consumption improvements.

Automobile dominates the corridor market. Fuel price increases at 3% per year and bus and rail level of service improvements do not reduce this dominance by very much. Most of the fuel economy improvements come from automobile (see Table A5.13. Note how the All-Modes efficiency changes parallel the automobile efficiency changes).

In the Montreal-Toronto link, CTOL is the largest mode. Fare changes, as in scenario C', show ability to cause significant modal shifts from, and discourage travel on, CTOL.

Indirect energy is a significant portion of the total energy consumption.

Improvements in vehicle energy consumption and public mode load factors are most important in reducing energy consumption. Modal shift strategies as examined in this thesis had only relatively small impacts. The results suggest that to encourage modal shifts large enough to have much impact on energy consumption, more drastic modifications of the system than tried here are necessary.

Access energy consumption is not a major factor in intercity energy consumption when automobile is included as an intercity mode. (That is, if door-to-door travel by car is viewed as a line-haul journey.) Access is most important in bus energy consumption, between 12 and 15% of the total.

6.3 Extensions

Improved fuel consumption statistics would be valuable in reducing possible error in calculating energy consumption. Automobile consumption figures are subject to the most assumptions. Statistics Canada has recently begun a survey of automobile over-the-road fuel consumption⁴⁰. Unfortunately there is no urban/rural breakdown of fuel consumption provided, and this may be impractical to measure anyway. However, this data is a valuable addition.

Data on travel volumes is difficult to find and seems to vary from source to source. Volumes should be broken down into origin/destination and through travel, by trip purpose and interurban/rural. Automobile volume data is particularly difficult to find, probably because it is difficult to measure. Study into ways of improving automobile demand measurement, including load factor, or, alternatively, into ways of working with data such as traffic counts are needed.

Level of service variables such as trip time, fare, and access cost, and number of departures are difficult to gather. The Canpass system brought together this data subject to the same assumptions on all links, so that inter-link comparisons could be made. Canpass has not been updated in the corridor since 1976. A continuing program of data collection similar to Canpass, and including improved methodology, would improve reliability and ease of travel demand forecasting.

Energy consumption data forecasts of vehicles or modes planned or contemplated but not implemented is lacking. For instance some

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LRC trains are already delivered. Measurement of in-service fuel consumption will soon be possible. This should be done and the results made available.

The energy efficiency of modern railway electrification deserves study. What would the energy consumption of an electrified LRC train be?

In this thesis indirect energy was found to be about 35% of the total energy consumption. Indirect energy data is not very consistent between sources, and forecasts are rare. The IBI study²⁰, has been subject to much criticism. Differences between this thesis' results and the BMC study³⁹ results were larger in indirect energy. Since indirect energy is such a large portion of the total energy it deserves more study.

Access energy made up about 2.5% of the total energy consumption. Without automobile in the total the access portion is higher. Access characteristics were assumed to be relatively constant through 1991 although fuel economy of access modes was changed for each year. Calculation of access energy consumes almost as much effort as calculation of line-haul energy and yet it's contribution to the total is relatively small. Improvements to data for calculating access energy could be made but is the extra effort justified for planning intercity transportation? Perhaps access should be studied as part of urban transportation energy studies.

The demand model used in this thesis did not distinguish between business and non-business travel. ~~It~~ measures to modify and shift

travel demand are studied, there are likely to be significant differences between business and non-business market reactions. Multi-modal models including automobile and market differentiation to handle travel demand management are needed.

The results of this thesis suggest that to encourage modal shifts drastic modifications of the system are necessary. Drastic measures can bring prediction out of a demand model's range. Study of traveller reaction to large changes in supply is needed.

This thesis used origin/destination travel. It seems likely that connecting and through travellers, as well as rural travellers, exhibit different characteristics than O/D travellers, particularly in mode choice. Study is needed to determine how the results of this or similar studies can be related to the energy actually used in the corridor. A straight ratio of O/D to total travel may not be sufficient to correctly calculate energy consumption.

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Appendix A

Background, and Demand and Energy

Input Data; and Supplementary

Output and Results Tables

This appendix contains the principal background data used in the thesis. The basic demand and energy input data is presented in some detail. Also included are detailed summaries of output from the demand model and energy calculations. Some summaries are also made and various tables containing other presentations of the results not shown in the text are included.

The numbering of Appendix A tables follows the chapters where corresponding discussion appears.

In many cases the names and captions of the tables in the appendix explain what they are.

Table A4.10 corresponds to Table 4.1 in the text. Table A4.10 presents travel totals for the system including the Toronto-Sudbury link in the totals. This is to enable comparison amongst scenarios Base, A, A', and C' with the Sudbury link included.

Tables A4.11 to A4.17 show detail of travel on each link, under each scenario.

Tables A4.39 to A4.62 show detailed energy consumption and efficiency figures for each scenario and mode. Line-haul and Total energy portions are shown. Tables A4.63 to A4.86 show similar details for access energy. These tables are included so the reader can undertake detailed examination of energy consumption under each scenario.

Table A2.1

Components of Energy for Several Train Consists

Components of Energy	E-8	P-30CH	Turboliner	LRC
Thermal Losses	70.3	66.3	88.9	70.0
Auxiliary Losses	6.0	6.2	2.5	7.3
Transmission Losses	4.5	4.5	1.6	4.2
Track Resistance	1.9	2.2	0.7	1.9
Rolling Resistance	6.5	7.2	2.3	6.6
Aerodynamic Drag	5.5	6.3	1.8	3.6
Acceleration	6.1	7.3	2.2	6.4
Total	100 %	100 %	100 %	100 %

Notes: Actual track, fully loaded, 1977 NYC-Albany Corridor.
 The components of energy are defined in section 2.3.
 E-8 and P-30CH are conventional diesel-electric locomotives.
 P-30CH is more modern than E-8.
 Turboliner is a gas turbine-hydraulic powered. LRC is diesel-electric with improved consist design and body tilting. Useful power (rail tractive effort) varies from 7% to 18.5%.

Source: Reference 25

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Table A2.2

CTOL Direct Energy Consumption Estimates
 For Aircraft Shown in Table 2.3
 (Btu/Seat-mile)

Link	<u>1976</u>	<u>1986</u>	<u>1991</u>
Montreal-Quebec City	4798.36	4370.80	4370.80
Montreal-Ottawa/Hull	6880.68	5843.80	5843.80
Montreal-Toronto	3610.00	2998.92	2998.92
Toronto-Ottawa/Hull	4139.37	3511.85	3511.85
Toronto-Windsor	4125.45	4125.45	4125.45
Toronto-London	3791.87	3791.87	3791.87
Toronto-Sudbury	3789.14	3789.14	3789.14

Notes: Aircraft types shown in Table 2.3.

Consumption calculated, for all links except M-QC '86-'91 and M-T '76, from data provided by Reference 15.

Montreal-Quebec City, 1986 and 1991 and Montreal-Toronto, 1976 calculated from Reference 5.

Table A3.4

1976 Intercity In-mode and Total Travel Times

(hours: minutes)

	Auto	Rail	Bus	CTOL	
Montreal-Quebec City	2:48	2:59	2:30	0:40	in-mode
	2:48	3:53	3:22	2:01	total
Montreal-Ottawa/Hull	2:26	1:59	2:19	0:25	in-mode
	2:26	3:11	3:34	2:12	total
Montreal-Toronto	6:34	4:10	6:20	1:00	in-mode
	6:34	5:37	7:49	3:11	total
Toronto-Ottawa/Hull	5:32	5:30	5:05	0:45	in-mode
	5:32	6:43	6:15	2:41	total
Toronto-Windsor	4:42	3:50	4:55	0:45	in-mode
	4:42	4:59	6:03	2:32	total
Toronto-London	2:04	1:55	2:20	0:35	in-mode
	2:04	3:03	3:25	2:28	total
Toronto-Sudbury	5:40	6:05	5:50	0:50	in-mode
	5:40	7:19	6:53	2:56	total

Notes: total travel time is in-mode time plus access, egress, and process time.

Source: Reference 27.

Table A2.4

Automobile Fuel Consumption
(Btu/Vehicle-Mile)

	<u>1975</u>	<u>1985</u>	<u>1990</u>
Highway (Rural)	7173	5968	4813
Urban	9816	8289	5526

Notes: Figures for 1976, 1981, 1991 were not available, therefore 1975, 1985 and 1990 were used.

Source: Reference 10.

Table A2.5

Intercity Bus Fuel Consumption
(Btu/Seat-Mile)

	<u>1976,1986</u>	<u>1991</u>
Highway (Rural)	533	480
Urban	890	802

Notes: 26,000 pound bus, 46 seats, 50-55 mph. average speed for urban consumption multiply by 1.67., Reference 21

Source: References 10,20

Table A2.6

1976 Passenger Rail Direct
Energy Consumption

<u>Link</u>	<u>Consumption</u> Btu/Seat-Mile	
Montreal-Quebec City	674.5	*
Montreal-Ottawa/Hull	1179.4	**
Montreal-Toronto	1311.3	**
Toronto-Ottawa ⁶ /Hull	1282.6	**
Toronto-Windsor	1022.0	**
Toronto-London	1022.0	**
Toronto-Sudbury	2084.6	+

* 1973 figures

** 1977 figures

+ 1977 transcontinental train consumption between Montreal & Ottawa.

Consumptions calculated from 1973 and 1977 data reported in Reference 7.

Table A2.7

LRC Passenger Rail Direct Energy Efficiency
(Btu/Seat-Mile)

Average Block Speed (MPH)	1-3-0 152 seats	1-4-0 228 seats	1-5-0 304 seats	1-5-0 388 seats
50	838	638	536	420
60	917	699	587	460
70	997	760	638	500
80	1157	881	740	580
90	1296	988	830	650
100	1416	1079	906	710

Note: LRC in service for 1986, 1991 years

Source: References 7, 10

Table A3.1

Modal Intercity Distances

(miles)

Link	CTOL	Rail	Bus		Auto		Great Circle
			Rural	Urban	Rural	Urban	
Montreal-Quebec City	146	152	139	16	139	16	145
Montreal-Ottawa/Hull	124	116	98	27	98	25	102
Montreal-Toronto	353	335	323	33	323	39	316
Toronto-Ottawa/Hull	258	277	251	22	251	32	218
Toronto-Windsor	194	224	213	21	211	10	207
Toronto-London	88	115	95	21	107	9	107
Toronto-Sudbury	211	260	238	12	233	8	210

Notes: Great circle distances from Reference 7, except Toronto-Sudbury which was calculated.

General source for other distances: Reference 27.

Montreal-Ottawa/Hull, Montreal-Toronto, and Toronto-Ottawa/Hull CTOL distances were developed from aeronautical charts: NTS 31SE, and Terminal Area Charts: Canada and North Atlantic, Enroute Low Altitude, LE7, LE8, published by the Surveys and Mapping Branch, Department of Energy Mines and Resources; and information on normal aircraft routings from W. R. Brooks, Ministry of Transport, Ottawa, personal communication.

Auto and bus urban and rural distances were developed as described in Appendix C.

Table A3.2

1976 Public Mode Daily Departure Frequency

City Pair	Rail	Bus	CTOL
Montreal-Quebec City	7	21	13
Montreal-Ottawa/Hull	7	18	15
Montreal-Toronto	4	6	26
Toronto-Ottawa/Hull	2	11	20
Toronto-Windsor	5	7	10
Toronto-London	11	8	9
Toronto-Sudbury	2	4	4

Notes: Values are number of departures in each direction.

Source: Reference 27.

Table A3.3

Intercity Mode Load Factors, 1977

City Pair	Load Factor (% of Capacity)			
	Auto	Bus	Rail	CTOL
Montreal-Quebec City	34	55	37	62
Montreal-Ottawa/Hull	30	69	36	53
Montreal-Toronto	34	43	50	67
Toronto-Ottawa/Hull	32	41	35*	67
Toronto-Windsor	34	55	37	61
Toronto-London	29	55	29	44
Toronto-Sudbury	34	43	36	67

Notes: Toronto-Sudbury used load factors of Toronto-Montreal because of similar distances except for Rail which was assigned a load factor of 36% as being typical of the transcontinental rail service.

- * Toronto-Ottawa/Hull rail was assigned 35%. The principal source stated 57%, which was a large increase from 34.6% supplied by Canadian Transport Commission to Khan, et.al. in their study "Intercity Passenger Transport Energy Efficiency" for 1976, Rail, Reference 7.

Lack of as complete load factor data for 1976 lead to the use of this 1977 data, as being representative of 1976 load factors, in energy calculations for 1976 consumption.

Sources: References 39, 7.

Table A3.4

1976 Intercity In-mode and Total Travel Times

(hours: minutes)

	Auto	Rail	Bus	CTOL	
Montreal-Quebec City	2:48	2:59	2:30	0:40	in-mode
	2:48	3:53	3:22	2:01	total
Montreal-Ottawa/Hull	2:26	1:59	2:19	0:25	in-mode
	2:26	3:11	3:34	2:12	total
Montreal-Toronto	6:34	4:10	6:20	1:00	in-mode
	6:34	5:37	7:49	3:11	total
Toronto-Ottawa/Hull	5:32	5:30	5:05	0:45	in-mode
	5:32	6:43	6:15	2:41	total
Toronto-Windsor	4:42	3:50	4:55	0:45	in-mode
	4:42	4:59	6:03	2:32	total
Toronto-London	2:04	1:55	2:20	0:35	in-mode
	2:04	3:03	3:25	2:28	total
Toronto-Sudbury	5:40	6:05	5:50	0:50	in-mode
	5:40	7:19	6:53	2:56	total

Notes: total travel time is in-mode time plus access, egress, and process time.

Source: Reference 27.

Table A3.5

1976 Intercity Fares and Total Trip Costs
(1976 Dollars)

	Auto	Rail	Bus	CTOL	
Montreal-Quebec City	12.87	8.50	7.70	28.00	fare
	12.87	14.21	13.20	34.15	total trip
Montreal-Ottawa/Hull	10.71	6.00	6.25	20.00	fare
	10.71	11.07	11.39	25.43	total trip
Montreal-Toronto	31.73	20.25	16.70	42.00	fare
	31.73	25.70	22.20	48.04	total trip
Toronto-Ottawa/Hull	24.92	15.50	13.20	36.00	fare
	24.92	20.28	18.22	41.65	total trip
Toronto-Windsor	23.34	11.75	11.70	33.00	fare
	23.34	16.74	16.67	38.43	total trip
Toronto-London	9.55	9.25	6.45	23.00	fare
	9.55	11.21	11.36	28.59	total trip
Toronto-Sudbury	25.00	20.00	14.10	35.00	fare
	25.00	25.10	18.96	40.90	total trip

Notes: Fare is the ticket cost of the line-haul portion of the trip.
Total trip cost is fare plus access and egress costs.

Source: Reference 27.

Table A3.6

1976 Populations and Projections for 1986 and 1991
(thousands)

	1976	1986	1991
Quebec City	542.2	616.0	651.5
Montreal	2802.5	2902.0	2941.5
Ottawa/Hull	693.3	805.1	854.0
Toronto	2803.1	3222.5	3403.5
Windsor	247.6	256.0	260.0
London	270.4	308.5	325.0
Sudbury	157.0	168.0	172.5

Notes: Cities here are Census Metropolitan Areas.

Source: Reference 28, Table 7, except Ottawa/Hull, 1986 and 1991,
which are from Table 6.

Table A3.7

1976 Incomes and Projections for 1986 and 1991

Disposable Income per Capita, 1976 Dollars

City	1976	1986	1991
Quebec City	5483.5	7358.7	8521.9
Montreal	6025.7	7647.1	8621.4
Ottawa/Hull	6597.8	8646.2	9734.8
Toronto	6884.6	8614.3	9663.5
Windsor	6794.3	8423.3	9511.7
London	6349.1	8427.7	9218.4
Sudbury	6855.4	8097.2	9002.5

Notes: 1976, 1981, 1986, 1991 incomes are given, in 1971 dollars, in: "Population and Income - estimates for 1976 and forecasts to 1991 for selected Provinces, Census Metropolitan Areas and Census Agglomerations", DERA, Transport Canada, December 1978, Table 10, Reference 28.

Conversion to 1976 dollars using information in SC62-010, March 1979, Tables 8 & 9. Quebec City, Montreal, Ottawa/Hull, and Toronto individual city CPI rates are given. Windsor, London and Sudbury incomes are converted using the Canadian national CPI.

Table A3.8

Language Pairing Indices

From:	To:	Montreal	Toronto
Quebec City		0.8539	-
Montreal		-	0.5953
Ottawa/Hull		0.7418	0.8757
Toronto		0.5953	-
Windsor		-	0.9935
London		-	0.9973
Sudbury		-	0.9492

Note: Language proportions were assumed to be constant from 1971 to 1991.

Source: Reference 41.

Table A4.1

Access Costs
(1976 cents)

Link	Year	CTOL	Rail	Bus
Montreal-Quebec City	1976	615	571	550
	1986	774	718	692
	1991	872	810	780
Montreal-Ottawa/Hull	1976	543	507	514
	1986	683	638	647
	1991	770	719	729
Montreal-Toronto	1976	604	545	550
	1986	760	686	692
	1991	857	773	780
Toronto-Ottawa/Hull	1976	565	478	502
	1986	711	601	631
	1991	801	678	712
Toronto-Windsor	1976	543	499	497
	1986	683	628	625
	1991	770	708	705
Toronto-London	1976	559	496	491
	1986	703	624	618
	1991	793	704	696
Toronto-Sudbury	1976	590	510	486
	1986	742	642	611
	1991	837	723	689

Notes: Figures from this table used in all scenarios except A'
Calculation details in Appendix G.

Table A4.2

Line-Haul Costs
(1976 cents)

Link	Year	Auto	CTOL	Rail	Bus
Montreal-Quebec City	1976	1287	2800	850	770
	1986	1619	2990	868	790
	1991	1826	3108	880	802
Montreal-Ottawa/Hull	1976	1071	2000	600	625
	1986	1347	2136	613	641
	1991	1519	2220	621	651
Montreal-Toronto	1976	3173	4200	2025	1670
	1986	3991	4485	2068	1713
	1991	4501	4662	2095	1740
Toronto-Ottawa/Hull	1976	2492	3600	1550	1320
	1986	3135	3844	1583	1354
	1991	3535	3996	1604	1375
Toronto-Windsor	1976	2334	3300	1175	1170
	1986	2936	3524	1200	1200
	1991	3311	3663	1216	1219
Toronto-London	1976	955	2300	625	645
	1986	1201	2456	638	662
	1991	1355	2553	647	672
Toronto-Sudbury	1976	2500	3500	2000	1410
	1986	3145	3737	2043	1446
	1991	3546	3885	2070	1469

Notes: Figures from this table used in all scenarios except A'.

Calculation details in Appendix G.

Table A4.3

Total Trip Costs

(1976 cents)

Link	Year	Auto	CTOL	Rail	Bus
Montreal-Quebec City	1976	1287	3415	1421	1320
	1986	1619	3764	1586	1482
	1991	1826	3980	1690	1582
Montreal-Ottawa/Hull	1976	1071	2543	1107	1139
	1986	1347	2819	1251	1288
	1991	1519	2990	1340	1380
Montreal-Toronto	1976	3173	4804	2570	2220
	1986	3991	5245	2754	2405
	1991	4501	5519	2868	2520
Toronto-Ottawa/Hull	1976	2492	4165	2028	1822
	1986	3135	4555	2184	1985
	1991	3535	4797	2282	2087
Toronto-Windsor	1976	2334	3843	1674	1667
	1986	2936	4207	1828	1825
	1991	3311	4433	1924	1924
Toronto-London	1976	955	2859	1121	1136
	1986	1201	3159	1262	1280
	1991	1355	3346	1351	1368
Toronto-Sudbury	1976	2500	4090	2510	1896
	1986	3145	4479	2685	2057
	1991	3546	4722	2793	2158

Notes: Figures from this table used in all scenarios except A'.

Calculation details in Appendix G.

Table A4.4

Scenario B' Rail Total Trip Costs
(1976 cents)

Link	Costs for 1986 & 1991
Montreal-Quebec City	1846
Montreal-Ottawa/Hull	1407
Montreal-Toronto	3583
Toronto-Ottawa/Hull	2803
Toronto-Windsor	2262
Toronto-London	1434

Note: B' rail costs are: (line-haul costs x 1.5) + (access/egress costs)

Table A4.5

Scenario C' CTOL Total Trip Costs
(1976 cents)

Link	1986	1991
Montreal-Quebec City	4362	4688
Montreal-Ottawa/Hull	3246	3434
Montreal-Toronto	6142	6451
Toronto-Ottawa/Hull	5324	5596
Toronto-Windsor	4912	5166
Toronto-London	3650	3857
Toronto-Sudbury	5226	5499

Note: C' CTOL total trip cost is: (scenario A line-haul cost x 1.2) +
(scenario A access/egress cost)

Table A4.6

Scenario A' Access Costs

(1976 cents)

Link	Year	CTOL	Rail	Bus
Montreal-Quebec City	1976	615	571	550
	1986	654	606	584
	1991	491	456	439
Montreal-Ottawa/Hull	1976	543	507	514
	1986	577	539	546
	1991	434	405	410
Montreal-Toronto	1976	604	545	550
	1986	642	579	584
	1991	482	435	439
Toronto-Ottawa/Hull	1976	565	478	502
	1986	600	507	533
	1991	451	382	401
Toronto-Windsor	1976	543	499	497
	1986	577	530	528
	1991	434	399	397
Toronto-London	1976	559	496	491
	1986	594	527	522
	1991	446	396	392
Toronto-Sudbury	1976	590	510	486
	1986	627	542	516
	1991	471	407	388

Note: Calculation details in Appendix G.

Table A4.7

Scenario A' Line-Haul Costs
(1976 cents)

Link	Year	Auto	CTOL	Rail	Bus
Montreal-Quebec City	1976	1287	2800	850	770
	1986	1403	2924	865	790
	1991	1314	3031	876	793
Montreal-Ottawa/Hull	1976	1071	2000	600	625
	1986	1169	2056	592	641
	1991	1080	2127	597	644
Montreal-Toronto	1976	3173	4200	2025	1670
	1986	3465	4485	1995	1713
	1991	3245	4662	2010	1720
Toronto-Ottawa/Hull	1976	2492	3600	1550	1320
	1986	2716	3699	1518	1354
	1991	2541	3828	1528	1360
Toronto-Windsor	1976	2334	3300	1175	1170
	1986	2542	3524	1163	1200
	1991	2400	3663	1172	1205
Toronto-London	1976	955	2300	625	645
	1986	1041	2456	619	662
	1991	979	2553	624	664
Toronto-Sudbury	1976	2500	3500	2000	1410
	1986	2722	3737	2043	1446
	1991	2575	3885	2070	1453

Notes: Calculation details in Appendix G.

Table A4.8

Scenario A' Total Trip Costs

(1976 cents)

Link	Year	Auto	CTOL	Rail	Bus
Montreal-Quebec City	1976	1287	3415	1421	1320
	1986	1403	3578	1471	1374
	1991	1314	3522	1332	1232
Montreal-Ottawa/Hull	1976	1071	2543	1107	1139
	1986	1169	2633	1131	1187
	1991	1080	2561	1002	1054
Montreal-Toronto	1976	3173	4804	2570	2220
	1986	3465	5127	2574	2297
	1991	3245	5144	2445	2159
Toronto-Ottawa/Hull	1976	2492	4165	2028	1822
	1986	2716	4299	2025	1887
	1991	2541	4279	1910	1761
Toronto-Windsor	1976	2334	3843	1674	1667
	1986	2543	4101	1693	1728
	1991	2400	4097	1571	1602
Toronto-London	1976	955	2859	1121	1136
	1986	1041	3050	1146	1184
	1991	979	2999	1020	1056
Toronto-Sudbury	1976	2500	4090	2510	1856
	1986	2722	4364	2585	1962
	1991	2575	4356	2477	1841

Note: Calculation details in Appendix G.

Table A4.9

Rail Total Trip Times at 100 mph. Line-Haul Speeds

Link	Minutes	Hours:Minutes
Montreal-Quebec City	145	2:25
Montreal-Ottawa/Hull	142	2:22
Montreal-Toronto	288	4:48
Toronto-Ottawa/Hull	239	3:59
Toronto-Windsor	203	3:23
Toronto-London	137	2:17

Table A4.10
Total Travel System With Sudbury
(Annual Trips)

Year	Scenario	Total Trips	Automobile	CTOL	Rail	Bus
1976	Base	17476000	12304000	1825000	1179000	2169000
1986	Base	23870000	16284000	2779000	1621000	3186000
	A	23248000	15359000	2865000	1705000	3332000
	B					
	C					
	A'	23639000	15921000	2738000	1716000	3264000
	B'					
	C'	23640000	15112000	2312000	2913000	3303000
1991	Base	28137000	18609000	3464000	2018000	4046000
	A	27090000	17008000	3617000	2177000	4288000
	B					
	C					
	A'	28328000	18244000	3253000	2246000	4585000
	B'					
	C'	27698000	16702000	2917000	3837000	4242000

Table A4.11

Total Travel
Montreal-Quebec City

Year	Scenario	Total Trips	Automobile		CTOL		Rail		Bus					
			Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.			
1976	Base	5572000	4675000	83.9	34	117000	2.1	62.0	78000	1.4	37.0	702000	12.6	55.0
1986	Base	7286000	6092000	83.6	34	152000	2.1	57.2	102000	1.4	48.2	940000	12.9	70.0
	A	7091000	5815000	82.0	34	163000	2.3	61.2	106000	1.5	50.3	1007000	14.2	70.0
	B	7347000	6005000	81.7	34	151000	2.1	56.7	265000	3.6	60.0	926000	12.6	68.9
	C	7194000	5763000	80.1	34	158000	2.2	56.7	273000	3.8	60.0	1000000	13.9	69.5
	A'	7221000	5980000	82.9	34	159000	2.2	59.7	108000	1.5	51.2	974000	13.5	70.0
	B'	7282000	6038000	83.0	34	153000	2.1	57.4	160000	2.2	56.9	931000	12.8	69.3
	C'	7180000	5781000	80.5	34	123000	1.7	60.0	275000	3.8	60.0	1001000	13.9	70.0
1991	Base	8567000	6990000	81.6	34	194000	2.3	60.0	117000	1.4	55.3	1266000	14.8	70.0
	A	8231000	6494000	78.9	34	222000	2.7	62.0	132000	1.6	60.0	1383000	16.8	70.0
	B	8781000	6944000	79.0	34	193000	2.2	59.6	387000	4.4	60.0	1257000	14.3	69.5
	C	8501000	6469000	76.1	34	221000	2.6	60.0	434000	5.1	60.0	1377000	16.2	70.0
	A'	8669000	6857000	79.1	34	191000	2.2	60.0	121000	1.4	60.0	1500000	17.3	70.0
	B'	8683000	6998000	80.6	34	200000	2.3	61.8	217000	2.5	60.0	1268000	14.6	70.0
	C'	8491000	6501000	76.6	34	172000	2.0	60.0	434000	5.1	60.0	1384000	16.3	70.0

Notes: Trips are per year.
Load factor (L.F.) in % of capacity

Table A4.13

Total Travel
Montreal-Toronto

Year	Scenario	Total Trips		Automobile		CTOL		Rail		Bus			
		Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.
1976	Base	2321000	32.3	34.0	948000	40.8	67.1	416000	17.9	50.0	207000	8.9	43.0
1986	Base	3176000	29.0	34.0	1478000	46.5	67.0	523000	16.5	60.0	254000	8.0	52.8
	A	3113000	26.5	34.0	1482000	47.6	70.0	545000	17.5	60.0	261000	8.4	54.4
	B	3265000	26.4	34.0	1380000	42.3	62.6	786000	24.1	56.9	238000	7.3	49.6
	C	3198000	24.0	34.0	1377000	43.1	65.1	812000	25.4	59.3	243000	7.6	50.6
	A'	3150000	28.4	34.0	1424000	45.2	67.0	573000	18.2	60.0	258000	8.2	53.8
	B'	3150000	29.8	34.0	1506000	47.8	67.0	443000	14.2	60.0	258000	8.2	53.8
	C'	3184000	25.4	34.0	1227000	38.5	60.0	894000	28.1	60.0	256000	8.0	53.3
1991	Base	3707000	27.1	34.0	1790000	48.3	67.0	634000	17.1	60.0	277000	7.5	57.7
	A	3628000	23.7	34.0	1799000	49.6	67.0	675000	18.6	60.0	294000	8.1	61.2
	B	3816000	24.6	34.0	1670000	43.8	62.5	949000	24.9	56.7	259000	6.8	54.0
	C	3694000	21.3	34.0	1647000	44.6	66.2	990000	26.8	60.0	270000	7.3	56.1
	A'	3703000	27.3	34.0	1653000	44.6	67.0	745000	20.1	60.0	293000	7.9	61.0
	B'	3676000	27.9	34.0	1827000	49.7	67.0	540000	14.7	60.0	283000	7.7	58.9
	C'	3606000	22.6	34.0	1445000	40.1	60.0	1069000	29.6	60.0	278000	7.7	57.9

Notes: Trips are per year.

Load factor (L.F.) in % of capacity.

Table A4.14

Total Travel
Toronto-Ottawa/Hull

Year	Scenario	Total Trips	Automobile		CTOL		Rail		Bus					
			Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.			
1976	Base	1933000	1101000	57.0	32.0	480000	24.8	67.1	70000	3.6	35.0	283000	14.6	41.0
1986	Base	2703000	1540000	57.0	32.0	671000	24.8	62.0	97000	3.6	49.0	395000	14.6	57.4
	A	2645000	1418000	53.6	32.0	706000	26.7	65.2	103000	3.9	51.9	418000	15.8	60.7
	B	2780000	1476000	53.1	32.0	642000	23.1	59.3	284000	10.2	60.0	378000	13.6	54.9
	C	2754000	1364000	49.5	32.0	680000	24.7	62.8	308000	11.2	60.0	402000	14.6	59.5
	A'	2682000	1494000	55.7	32.0	684000	25.5	63.1	102000	3.8	51.3	402000	15.0	58.5
	B'	2735000	1529000	55.9	32.0	665000	24.3	61.3	150000	5.5	56.7	391000	14.3	56.8
	C'	2705000	1399000	51.7	32.0	571000	21.1	60.0	323000	11.9	60.0	412000	15.2	61.9
1991	Base	3257000	1810000	55.6	32.0	869000	26.7	67.0	114000	3.5	57.6	464000	14.3	67.5
	A	3155000	1595000	50.6	32.0	933000	29.6	67.0	126000	4.0	60.0	501000	15.9	70.0
	B	3426000	1739000	50.6	32.0	835000	24.4	64.4	404000	11.8	60.0	448000	13.1	65.1
	C	3323000	1507000	50.8	32.0	883000	26.6	67.0	458000	13.8	60.0	475000	14.3	69.0
	A'	3259000	1799000	45.4	32.0	844000	25.9	66.9	127000	3.9	60.0	489000	15.0	69.8
	B'	3310000	1788000	55.2	32.0	857000	25.9	66.1	205000	6.2	60.0	460000	13.9	66.8
	C'	3275000	1536000	54.0	32.0	779000	23.8	62.0	476000	14.5	60.0	484000	14.8	70.0

Notes. Trips are per year.

Load factor (L.F.) in % of capacity.

Table A4.15

Total Travel
Toronto-Windsor

Year	Scenario	Total Trips	Automobile		CTOL		Rail		Bus					
			Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.			
1976	Base	1050000	790000	75.3	34.0	97000	9.2	61.0	118000	11.2	37.0	45000	4.3	55.1
1986	Base	1418000	1027000	72.4	34.0	174000	12.3	60.0	157000	11.1	53.4	60000	4.2	70.0
	A	1388000	963000	69.4	34.0	190000	13.7	60.0	168000	12.1	50.4	67000	4.8	70.0
	B	1475000	985000	66.8	34.0	167000	11.3	60.0	264000	17.9	52.9	59000	4.0	70.0
	C	1442000	917000	63.6	34.0	182000	12.6	60.0	280000	19.4	56.0	63000	4.4	70.0
	A'	1403000	1007000	71.7	34.0	170000	12.1	60.0	164000	11.7	55.7	62000	4.4	70.0
	B'	1442000	1008000	69.9	34.0	172000	11.9	60.0	203000	14.1	59.5	59000	4.1	70.0
	C'	1406000	922000	65.6	34.0	138000	9.8	60.0	282000	20.0	55.7	64000	4.5	70.0
1991	Base	1686000	1168000	69.3	34.0	230000	13.6	60.0	208000	12.4	46.9	80000	4.7	70.0
	A	1631000	1054000	64.6	34.0	259000	15.9	60.0	228000	14.0	51.5	90000	5.5	70.0
	B	1753000	1112000	63.4	34.0	217000	12.4	60.0	349000	19.9	52.4	75000	4.3	70.0
	C	1696000	993000	58.5	34.0	243000	14.3	60.0	377000	22.2	56.6	83000	4.9	70.0
	A'	1685000	1161000	68.9	34.0	209000	12.4	60.0	226000	13.4	58.4	89000	5.3	70.0
	B'	1717000	1145000	66.7	34.0	225000	13.1	60.0	270000	15.7	58.6	77000	4.5	70.0
	C'	1674000	1013000	60.6	34.0	190000	11.3	60.0	385000	23.0	62.4	86000	5.1	70.0

Notes: Rail 1986, 1991, Load factors are distance weighted averages.
Energy calculations use a more detailed L.F. breakdown.
1986 2190 trains per year.

1991 2920 trains per year.
Trips are per year.
Load factor (L.F.) in % of capacity

Table A4.16

Total Travel
Toronto-London

Year	Scenario	Total Trips	Automobile		CTOL		Rail		Bus					
			Trips	Share %	L.F.	Trips	Share %	L.F.	Trips	Share %	L.F.			
1976	Base	2598000	2139000	82.3	29.0	31000	1.2	44.0	293000	11.3	29.0	135000	5.2	54.9
1986	Base	3744000	3008000	80.3	29.0	45000	1.2	60.0	478000	12.8	53.7	213000	5.7	70.0
	A	3637000	2859000	78.7	29.0	51000	1.4	60.0	505000	13.9	56.9	222000	6.1	70.0
	B	3831000	2888000	75.3	29.0	42000	1.1	60.0	698000	18.2	56.9	203000	5.3	70.0
	C	3720000	2727000	73.3	29.0	48000	1.3	60.0	733000	19.7	59.9	212000	5.7	70.0
	A'	3698000	2940000	79.5	29.0	44000	1.2	60.0	496000	13.4	55.8	218000	5.9	70.0
	B'	3781000	2957000	78.2	29.0	45000	1.2	60.0	567000	15.0	57.5	212000	5.6	70.0
C'	3714000	2727000	73.4	29.0	42000	1.1	60.0	733000	19.7	60.0	212000	5.7	70.0	
1991	Base	4506000	3499000	77.6	29.0	63000	1.4	60.0	649000	14.4	54.4	295000	6.6	70.0
	A	4308000	3231000	75.0	29.0	69000	1.6	60.0	698000	16.2	57.1	310000	7.2	70.0
	B	4626000	3340000	72.2	29.0	60000	1.3	60.0	944000	20.4	57.4	282000	6.1	70.0
	C	4420000	3059000	69.2	29.0	66000	1.5	60.0	1003000	22.7	61.2	292000	6.6	70.0
	A'	4538000	3418000	75.4	29.0	59000	1.3	60.0	712000	15.7	59.5	349000	7.7	70.0
	B'	4559000	3434000	75.4	29.0	64000	1.4	60.0	770000	16.9	54.9	291000	6.4	70.0
C'	4414000	3059000	69.3	29.0	57000	1.3	60.0	1004000	22.8	61.6	294000	6.7	70.0	

Notes: 1986, 1991 Rail Load Factors are averages. A more detailed breakdown of load factors is used in energy calculations.
 1986 4380 trains per year.
 1991 5840 trains per year.
 Load factor (L.F.) in % of capacity.
 Trips per year.

Table A4.17

Total Travel
Toronto-Sudbury

Year	Scenario	Total Trips	Automobile		CTOL		Trips		L.F.		Trips		Rail		Trips		Bus		L.F.	
			Trips	Share	Share	Share	Trips	Share	Share	Share	Trips	Share	Share	Share	Trips	Share	Share	Share	Share	Share
1976	Base	543000	300000	55.2	34.0	34.0	90000	16.6	67.0	31000	5.7	36.0	122000	22.5	43.0					
1986	Base	763000	387000	50.7	34.0	34.0	178000	23.3	60.0	40000	5.2	36.0	158000	20.7	55.5					
	A	744000	354000	47.5	34.0	34.0	183000	24.6	60.0	42000	5.7	38.2	165000	22.2	58.2					
	B																			
	C																			
	A'	753000	378000	50.2	34.0	34.0	172000	22.8	60.0	41000	5.5	37.3	162000	21.5	57.0					
1991	B'																			
	C'	710000	359000	50.6	34.0	34.0	140000	19.7	60.0	43000	6.1	38.7	168000	23.7	59.1					
1991	Base	884000	434000	49.1	34.0	34.0	228000	25.8	60.0	45000	5.1	40.4	177000	20.0	62.2					
	A	851000	378000	44.4	34.0	34.0	235000	27.6	60.0	49000	5.8	44.6	189000	22.2	66.6					
	B																			
	C																			
	A'	878000	434000	49.5	34.0	34.0	210000	23.9	60.0	47000	5.3	41.9	187000	21.3	65.8					
1991	B'																			
	C'	832000	396000	47.6	34.0	34.0	186000	22.3	60.0	52000	6.2	46.9	198000	23.8	69.7					

Notes: Trips are per year.

Load factor (L.F.) in % of capacity.

Table A4.18

Total Effective Passenger Miles System Without Sudbury

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	2.81115×10^9	1.80729×10^9	4.50895×10^8	2.31453×10^8	3.21506×10^8
1986	Base	3.83207×10^9	2.38207×10^9	6.84457×10^8	3.07699×10^8	4.56815×10^8
	A	3.73838×10^9	2.23699×10^9	6.99618×10^8	3.22927×10^8	4.78823×10^8
	B	3.91289×10^9	2.31144×10^9	6.45158×10^8	5.12533×10^8	4.43526×10^8
	C	3.83520×10^9	2.17435×10^9	6.57862×10^8	5.36532×10^8	4.66429×10^8
	A'	3.79585×10^9	2.32779×10^9	6.70713×10^8	3.29650×10^8	4.67734×10^8
	B'	3.84294×10^9	2.36792×10^9	6.91838×10^8	3.27890×10^8	4.55293×10^8
	C'	3.80891×10^9	2.19880×10^9	5.70347×10^8	5.66620×10^8	4.73174×10^8
1991	Base	4.51883×10^9	2.71985×10^9	8.46741×10^8	3.80258×10^8	5.72047×10^8
	A	4.36554×10^9	2.47139×10^9	8.75256×10^8	4.09228×10^8	6.09604×10^8
	B	4.65961×10^9	2.64574×10^9	7.98050×10^8	6.57304×10^8	5.58537×10^8
	C	4.50014×10^9	2.39244×10^9	8.12242×10^8	7.03507×10^8	5.91495×10^8
	A'	4.54282×10^9	2.67572×10^9	7.92485×10^8	4.30953×10^8	6.43614×10^8
	B'	4.55620×10^9	2.70985×10^9	8.55763×10^8	4.18735×10^8	5.71914×10^8
	C'	4.45488×10^9	2.41678×10^9	7.05785×10^8	7.34159×10^8	5.98138×10^8

Table A4.19

Total Effective Passenger Miles System With Sudbury

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	2.92518×10^9	1.87029×10^9	4.69795×10^8	2.37963×10^8	3.47126×10^8
1986	Base	3.99128×10^9	2.46334×10^9	7.21837×10^8	3.16099×10^8	4.89995×10^8
	A	3.89462×10^9	2.31133×10^9	7.38048×10^8	3.31747×10^8	5.13473×10^8
	B					
	C					
	A'	3.95398×10^9	2.40717×10^9	7.06833×10^8	3.29650×10^8	5.01754×10^8
	B'					
	C'	3.95801×10^9	2.27419×10^9	5.99747×10^8	5.75650×10^8	5.08454×10^8
1991	Base	4.70447×10^9	2.81099×10^9	8.94621×10^8	3.89708×10^8	6.09217×10^8
	A	4.54425×10^9	2.55077×10^9	9.24606×10^8	4.19518×10^8	6.49294×10^8
	B					
	C					
	A'	4.72720×10^9	2.75686×10^9	8.36585×10^8	4.40823×10^8	6.82884×10^8
	B'					
	C'	4.62960×10^9	2.49994×10^9	7.44845×10^8	7.45079×10^8	6.39718×10^8

Table A4.20

Total User Trip Cost System Without Sudbury
(1976 Dollars)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	3.02673×10^8	1.77568×10^8	7.57202×10^7	2.52534×10^7	2.89901×10^7
1986	Base	4.17586×10^8	2.34139×10^8	1.14174×10^8	2.73239×10^7	4.19446×10^7
	A	4.84592×10^8	2.76230×10^8	1.28109×10^8	3.13362×10^7	4.89157×10^7
	B	4.21439×10^8	2.27021×10^8	1.07844×10^8	4.57440×10^7	4.08274×10^7
	C	4.89136×10^8	2.68268×10^8	1.20742×10^8	5.23045×10^7	4.78212×10^7
	A'	4.42211×10^8	2.49415×10^8	1.18654×10^8	2.94878×10^7	4.46495×10^7
	B'	4.29591×10^8	2.32790×10^8	1.15252×10^8	3.97660×10^7	4.17794×10^7
	C'	4.96579×10^8	2.71467×10^8	1.21744×10^8	5.49834×10^7	4.83786×10^7
1991	Base	4.95797×10^8	2.67310×10^8	1.41740×10^8	3.38043×10^7	5.29363×10^7
	A	6.22188×10^8	3.43935×10^8	1.69659×10^8	4.18864×10^7	6.67062×10^7
	B	5.04335×10^8	2.59775×10^8	1.33888×10^8	5.88451×10^7	5.18272×10^7
	C	6.28016×10^8	3.32499×10^8	1.57933×10^8	7.25719×10^7	6.49997×10^7
	A'	5.00856×10^8	2.68459×10^8	1.40432×10^8	3.57507×10^7	5.62144×10^7
	B'	5.13080×10^8	2.66247×10^8	1.43058×10^8	5.08924×10^7	5.28822×10^7
	C'	6.36968×10^8	3.36023×10^8	1.59909×10^8	7.54148×10^7	6.56261×10^7

Table A4.21

Total User Trip Cost System With Sudbury
(1976 Dollars)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	3.16945×10^8	1.85068×10^8	7.94012×10^7	2.75665×10^7	3.13032×10^7
1986	Base	4.38478×10^8	2.43814×10^8	1.21454×10^8	2.83279×10^7	4.48771×10^7
	A	5.08444×10^8	2.87363×10^8	1.36306×10^8	3.24639×10^7	5.23097×10^7
	B					
	C					
	A'	4.64245×10^8	2.59704×10^8	1.26160×10^8	3.05477×10^7	4.78279×10^7
	B'					
	C'	5.19796×10^8	2.82758×10^8	1.29060×10^8	5.61380×10^7	5.18344×10^7
1991	Base	5.20458×10^8	2.78160×10^8	1.51065×10^8	3.49338×10^7	5.62922×10^7
	A	6.52136×10^8	3.57449×10^8	1.80756×10^8	4.32550×10^7	7.07848×10^7
	B					
	C					
	A'	5.25786×10^8	2.79635×10^8	1.49580×10^8	3.69149×10^7	5.96571×10^7
	B'					
	C'	6.65964×10^8	3.50065×10^8	1.70137×10^8	7.68672×10^7	6.98989×10^7

Table A4.22

Total User Trip Time System Without Sudbury
(Minutes)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	3.44861×10^9	2.30560×10^9	3.00023×10^8	3.08518×10^8	5.33473×10^8
1986	Base	4.68427×10^9	3.04336×10^9	4.52522×10^8	4.16308×10^8	7.72105×10^8
	A	4.56471×10^9	2.85509×10^9	4.64497×10^8	4.37600×10^8	8.07491×10^8
	B	4.66009×10^9	2.95194×10^9	4.27371×10^8	5.30311×10^8	7.50412×10^8
	C	4.55517×10^9	2.77436×10^9	4.37728×10^8	5.55579×10^8	7.87499×10^8
	A'	4.65131×10^9	2.97291×10^9	4.44911×10^8	4.43486×10^8	7.89926×10^8
	B'	4.59780×10^9	3.02575×10^9	4.56861×10^8	3.45728×10^8	7.69447×10^8
	C'	4.56651×10^9	2.80687×10^9	3.77738×10^8	5.83754×10^8	7.98112×10^8
1991	Base	5.51991×10^9	3.47533×10^9	5.61438×10^8	5.15764×10^8	9.67375×10^8
	A	5.31968×10^9	3.15307×10^9	5.83462×10^8	5.56295×10^8	1.02685×10^9
	B	5.53654×10^9	3.37912×10^9	5.30243×10^8	6.81822×10^8	9.45345×10^8
	C	5.32089×10^9	3.05018×10^9	5.42989×10^8	7.30665×10^8	9.97109×10^8
	A'	5.61232×10^9	3.41943×10^9	5.26695×10^8	5.79506×10^8	1.08674×10^9
	B'	5.43765×10^9	3.46145×10^9	5.66692×10^8	4.43140×10^8	9.66336×10^8
	C'	5.32022×10^9	3.08178×10^9	4.71164×10^8	7.59479×10^8	1.00779×10^9

Table A4.23

Total User Trip Time System With Sudbury
(Minutes)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	3.63045×10^9	2.40860×10^9	3.15863×10^8	3.22127×10^8	5.83859×10^8
1986	Base	4.92999×10^9	3.17494×10^9	4.83850×10^8	4.33868×10^8	8.37359×10^8
	A	4.80386×10^9	2.97545×10^9	4.96705×10^8	4.56038×10^8	8.75636×10^8
	B					
	C					
	A'	4.89501×10^9	3.10143×10^9	4.75183×10^8	4.61485×10^8	8.56832×10^8
	B'					
	C'	4.80147×10^9	2.92893×10^9	4.02378×10^8	6.02631×10^8	8.67496×10^8
1991	Base	5.80045×10^9	3.62289×10^9	6.01566×10^8	5.35519×10^8	1.04048×10^9
	A	5.58913×10^9	3.28159×10^9	6.24822×10^8	5.77806×10^8	1.10491×10^9
	B					
	C					
	A'	5.89470×10^9	3.56699×10^9	5.63655×10^8	6.00139×10^8	1.16397×10^9
	B'					
	C'	5.59220×10^9	3.21642×10^9	5.03900×10^8	7.82307×10^8	1.08956×10^9

Table A4.24

CTOL Indirect Energy Efficiency

Aircraft Seats	Energy to Produce fuel, % of direct consumption	Vehicle Production Btu/seat-mile	Vehicle Maintenance Btu/seat-mile	Infrastructure		Construction		Operation & Maintenance	
				Terminal Btu/Pass-Dep.	Runway System Btu/seat-served	Terminal Btu/Pass-Dep.	Runway System Btu/seat-served	Terminal Btu/Pass-Dep.	Runway System Btu/seat-served
DC-9-15	72	12.6	51	223	62,562	48,833	314,607	7,361	7,361
DC-9-32	102	12.6	43	158	62,562	48,833	314,607	7,361	7,361
B737-200	117	12.6	38	138	62,562	48,833	314,607	7,361	7,361
B727-200	144	12.6	44	112	62,562	48,833	314,607	7,361	7,361
B767	218	12.6	44	74	62,562	48,833	314,607	4,862	4,862
DHC7	50	12.6	78	231	25,320	13,693	126,869	2,667	2,667

Source: References 10, 20 and 46

Table A4.25
Passenger Rail Indirect Energy Efficiency

<u>Indirect Energy Item</u>	<u>Energy Efficiency</u>	
Energy to produce fuel	12.6% of fuel consumed	
Vehicle Production		
LRC 1-3-0 (152 seats)	11,613 Btu/Train-mile	76 Btu/Seat-mile
LRC 1-4-0 (228 seats)	13,674 Btu/Train-mile	60 Btu/Seat-mile
LRC 1-5-0 (304 seats)	15,729 Btu/Train-mile	52 Btu/Seat-mile
Vehicle Maintenance		
LRC 1-3-0	22,400 Btu/Train-mile	147 Btu/Seat-mile
LRC 1-4-0	26,950 Btu/Train-mile	118 Btu/Seat-mile
LRC 1-5-0	31,500 Btu/Train-mile	104 Btu/Seat-mile
Infrastructure Construction		
Terminal Track	43,822 Btu/Passenger-departure	
	364,444 Btu/Train-mile	
Infrastructure Operation & Maintenance		
Terminal Track	93,333 Btu/Passenger-departure	
	26,667 Btu/Train-mile	

Source: References 7, 20

Table A4.26

Bus and Automobile Line-haul Indirect Energy Efficiency

Indirect Energy Item	Bus, Urban Portion of Intercity Trip	Bus, Rural	Auto, Urban Portion of Intercity Trip	Auto, Rural
Energy to Produce Fuel	12.6%	12.6%	19.5%	19.5%
Vehicle Production	31	31	282	282
Vehicle Maintenance	79	79	176	176
Infrastructure Construction				
Roads	48 ⁺	26	154 ⁺⁺	119.6
Terminal	8,667 [*]	-	-	-
Infrastructure Operation and Maintenance				
Roads	11 ⁺	2.6	47.6 ⁺⁺	12
Terminal	15,000 [*]	-	-	-

Notes: Units are Btu/Seat-mile except energy to produce fuel in % of direct fuel consumption and
^{*} terminal consumption in Btu/Passenger-departure.

⁺ Assumes 50% expressway, 50% arterial in urban portion of intercity travel.

⁺⁺ Assumes urban arterial.

Freeway assumed for rural travel.

Source: References 7, 20.

Table A4.27

Automobile, Bus, and Mass Transit Access Energy Efficiency

	Auto/Taxi (Btu/S.M.)	Bus (Btu/P.M.)	Metro/Subway (Btu/P.M.)				
Direct Energy	*	**	1137				
Energy to Produce Fuel ⁺	19.5%	12.6%	756				
Vehicle Production	282	213	174				
Vehicle Maintenance	176	305	117				
Infrastructure Construction	154	210	1471				
Infrastructure Operation & Maintenance	47.5	65	333				
Ave. MPH:	15	20	25	30	35	40	45
* Btu/P.M.:	6894	6806	7034	7081	7011	7034	7090
**Btu/P.M.:	2995	2760	2693	2257	1933	2078	2302

Notes: For speeds less than 15 mph, linear regression used to calculate consumption. Speeds greater than 15 mph, linear interpolation used.

⁺Auto & Bus: ~~Energy~~ to produce fuel is percent of direct consumption.

Auto/Taxi load factor for terminal access is 28%.

Bus load factor is 11 passengers per 51 seats.

Auto/Taxi and Bus direct consumption, Reference 38.

All other consumption from Reference 20.

Table A4.28

Terminal Access Speeds and Distances

Intercity Mode	Access Mode	Quebec City		Montreal		Ottawa/Hull		Toronto	
		mph.	miles	mph.	miles	mph.	miles	mph.	miles
CTOL	Auto	27.3	8.66	19.7	6.53	13.8	5.61	27.7	12.7
	Bus	18.8	9.66	18.0	9.27	7.7	3.94	22.9	12.7
	Metro	-	-	18.0	9.27	-	-	22.9	12.7
	Taxi/Limo.	28.3	9.55	20.5	8.00	10.1	4.46	28.0	12.9
Rail	Auto	17.7	4.03	12.7	3.70	14.2	3.69	19.7	7.3
	Bus	7.6	3.26	9.0	3.48	7.8	2.69	12.1	5.2
	Metro	-	-	9.0	3.48	-	-	12.1	5.2
	Taxi/Limo.	7.9	1.97	10.7	2.39	10.6	2.54	13.2	4.6
Bus	Auto	11.7	3.06	16.2	4.29	10.9	3.02	17.8	7.4
	Bus	7.2	2.75	10.4	3.81	6.4	2.30	10.3	5.1
	Metro	-	-	10.4	3.81	-	-	10.3	5.1
	Taxi/Limo.	8.5	1.86	11.5	2.53	5.4	1.53	9.2	2.8
STOL	Auto	NA	NA	NA	6.3	NA	5.30	NA	7.0
	Bus	NA	NA	NA	6.3	NA	-	NA	7.0
	Metro	NA	NA	NA	6.3	NA	-	NA	7.0
	Taxi/Limo.	NA	NA	NA	6.3	NA	5.30	NA	7.0

Source: see text, pp. 52,53

Table A4.29

Terminal Access Speeds and Distances

Intercity Mode		Windsor	London	Sudbury
CTOL	mph	4.4	6.1	16.1
	miles	6	9	22
Rail	mph	12.5	9.6	8.2
	miles	5	4	14
Bus	mph	11.5	10.4	6.0
	miles	5	4	13

Note: All access is assumed to be by automobile.

Source: extracted from Canpass 3 data set, Reference 27.

Table A4.30

Montreal-Quebec City Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.5210 \times 10^{13}$	$.4770 \times 10^{13}$	$.2127 \times 10^{12}$	$.4445 \times 10^{11}$	$.1831 \times 10^{12}$
1986	Base	$.5909 \times 10^{13}$	$.5393 \times 10^{13}$	$.2699 \times 10^{12}$	$.4622 \times 10^{11}$	$.1992 \times 10^{12}$
	A	$.5688 \times 10^{13}$	$.5148 \times 10^{13}$	$.2804 \times 10^{12}$	$.4612 \times 10^{11}$	$.2134 \times 10^{12}$
	B	$.5905 \times 10^{13}$	$.5316 \times 10^{13}$	$.2699 \times 10^{12}$	$.1202 \times 10^{12}$	$.1987 \times 10^{12}$
	C	$.5721 \times 10^{13}$	$.5102 \times 10^{13}$	$.2824 \times 10^{12}$	$.1235 \times 10^{12}$	$.2131 \times 10^{12}$
	A'	$.5818 \times 10^{13}$	$.5294 \times 10^{13}$	$.2686 \times 10^{12}$	$.4872 \times 10^{11}$	$.2064 \times 10^{12}$
	B'	$.5891 \times 10^{13}$	$.5346 \times 10^{13}$	$.2710 \times 10^{12}$	$.7529 \times 10^{11}$	$.1989 \times 10^{12}$
	C'	$.5665 \times 10^{12}$	$.5118 \times 10^{12}$	$.2108 \times 10^{11}$	1.2458×10^{11}	2.1213×10^{11}
1991	Base	$.5797 \times 10^{13}$	$.5182 \times 10^{13}$	$.3255 \times 10^{12}$	$.4709 \times 10^{11}$	$.2418 \times 10^{12}$
	A	$.5492 \times 10^{13}$	$.4815 \times 10^{13}$	$.3634 \times 10^{12}$	$.5008 \times 10^{11}$	$.2642 \times 10^{12}$
	B	$.5887 \times 10^{13}$	$.5148 \times 10^{13}$	$.3254 \times 10^{12}$	$.1719 \times 10^{12}$	$.2415 \times 10^{12}$
	C	$.5622 \times 10^{13}$	$.4796 \times 10^{13}$	$.3708 \times 10^{12}$	$.1919 \times 10^{12}$	$.2630 \times 10^{12}$
	A'	$.5737 \times 10^{13}$	$.5084 \times 10^{13}$	$.3204 \times 10^{12}$	$.4624 \times 10^{11}$	$.2865 \times 10^{12}$
	B'	$.5862 \times 10^{13}$	$.5188 \times 10^{13}$	$.3355 \times 10^{11}$	$.9609 \times 10^{11}$	$.2422 \times 10^{12}$
	C'	$.5562 \times 10^{12}$	$.4819 \times 10^{12}$	$.2885 \times 10^{11}$	1.9254×10^{11}	2.6434×10^{11}

Table A4.31

Montreal-Ottawa/Hull Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.2793 \times 10^{13}$	$.2405 \times 10^{13}$	$.1430 \times 10^{12}$	$.1150 \times 10^{12}$	$.1303 \times 10^{12}$
1986	Base	$.3181 \times 10^{13}$	$.2710 \times 10^{13}$	$.1621 \times 10^{12}$	$.9007 \times 10^{11}$	$.2186 \times 10^{12}$
	A	$.3039 \times 10^{13}$	$.2559 \times 10^{13}$	$.1646 \times 10^{12}$	$.9171 \times 10^{11}$	$.2235 \times 10^{12}$
	B	$.3200 \times 10^{13}$	$.2681 \times 10^{13}$	$.1606 \times 10^{12}$	$.1401 \times 10^{12}$	$.2180 \times 10^{12}$
	C	$.3081 \times 10^{13}$	$.2551 \times 10^{13}$	$.1644 \times 10^{12}$	$.1429 \times 10^{12}$	$.2229 \times 10^{12}$
	A'	$.3120 \times 10^{13}$	$.2643 \times 10^{13}$	$.1631 \times 10^{12}$	$.9124 \times 10^{11}$	$.2227 \times 10^{12}$
	B'	$.3210 \times 10^{13}$	$.2708 \times 10^{13}$	$.1619 \times 10^{12}$	$.1219 \times 10^{12}$	$.2183 \times 10^{12}$
	C'	$.30621 \times 10^{12}$	$.25529 \times 10^{12}$	$.14250 \times 10^{11}$	$.14368 \times 10^{11}$	$.22308 \times 10^{11}$
1991	Base	$.2998 \times 10^{13}$	$.2494 \times 10^{13}$	$.1615 \times 10^{12}$	$.9113 \times 10^{11}$	$.2506 \times 10^{12}$
	A	$.2825 \times 10^{13}$	$.2288 \times 10^{13}$	$.1811 \times 10^{12}$	$.9911 \times 10^{11}$	$.2563 \times 10^{12}$
	B	$.3043 \times 10^{13}$	$.2482 \times 10^{13}$	$.1620 \times 10^{12}$	$.1482 \times 10^{12}$	$.2504 \times 10^{12}$
	C	$.2852 \times 10^{13}$	$.2278 \times 10^{13}$	$.1652 \times 10^{12}$	$.1537 \times 10^{12}$	$.2553 \times 10^{12}$
	A'	$.2944 \times 10^{13}$	$.2401 \times 10^{13}$	$.1617 \times 10^{12}$	$.9340 \times 10^{11}$	$.2882 \times 10^{12}$
	B'	$.3055 \times 10^{13}$	$.2488 \times 10^{13}$	$.1673 \times 10^{12}$	$.1448 \times 10^{12}$	$.2547 \times 10^{12}$
	C'	$.28522 \times 10^{12}$	$.22795 \times 10^{12}$	$.16220 \times 10^{11}$	$.15471 \times 10^{11}$	$.25582 \times 10^{11}$

Table A4.32

Montreal-Toronto Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.50665 \times 10^{13}$	$.1789 \times 10^{13}$	$.2593 \times 10^{13}$	$.5430 \times 10^{12}$	$.1414 \times 10^{12}$
1986	Base	$.5878 \times 10^{13}$	$.1907 \times 10^{13}$	$.3437 \times 10^{13}$	$.3909 \times 10^{12}$	$.1431 \times 10^{12}$
	A	$.5586 \times 10^{13}$	$.1708 \times 10^{13}$	$.3329 \times 10^{13}$	$.4062 \times 10^{12}$	$.1432 \times 10^{12}$
	B	$.6013 \times 10^{13}$	$.1782 \times 10^{13}$	$.3389 \times 10^{13}$	$.6997 \times 10^{12}$	$.1418 \times 10^{12}$
	C	$.5703 \times 10^{13}$	$.1586 \times 10^{13}$	$.3277 \times 10^{13}$	$.6983 \times 10^{12}$	$.1422 \times 10^{12}$
	A'	$.5735 \times 10^{13}$	$.1853 \times 10^{13}$	$.3312 \times 10^{13}$	$.4278 \times 10^{12}$	$.1429 \times 10^{12}$
	B'	$.5969 \times 10^{13}$	$.1944 \times 10^{13}$	$.3502 \times 10^{13}$	$.3809 \times 10^{12}$	$.1429 \times 10^{12}$
	C'	5.6949×10^{12}	1.6706×10^{12}	3.1188×10^{12}	7.6256×10^{11}	1.4301×10^{11}
1991	Base	$.6424 \times 10^{13}$	$.1743 \times 10^{13}$	$.4086 \times 10^{13}$	$.4660 \times 10^{12}$	$.1307 \times 10^{12}$
	A	$.6221 \times 10^{13}$	$.1490 \times 10^{13}$	$.4106 \times 10^{13}$	$.4938 \times 10^{12}$	$.1316 \times 10^{12}$
	B	$.6625 \times 10^{13}$	$.1625 \times 10^{13}$	$.4035 \times 10^{13}$	$.8355 \times 10^{12}$	$.1297 \times 10^{12}$
	C	$.6121 \times 10^{13}$	$.1363 \times 10^{13}$	$.3796 \times 10^{13}$	$.8306 \times 10^{12}$	$.1307 \times 10^{12}$
	A'	$.6205 \times 10^{13}$	$.1753 \times 10^{13}$	$.3773 \times 10^{13}$	$.5477 \times 10^{12}$	$.1316 \times 10^{12}$
	B'	$.6531 \times 10^{13}$	$.1777 \times 10^{13}$	$.4170 \times 10^{13}$	$.4529 \times 10^{12}$	$.1311 \times 10^{12}$
	C'	6.0502×10^{12}	1.4099×10^{12}	3.6107×10^{12}	8.9875×10^{11}	1.3077×10^{11}

Table A4.33

Toronto-Ottawa/Hull Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.3449 \times 10^{13}$	$.2056 \times 10^{13}$	$.1127 \times 10^{13}$	$.1076 \times 10^{12}$	$.1579 \times 10^{12}$
1986	Base	$.4180 \times 10^{13}$	$.2496 \times 10^{13}$	$.1451 \times 10^{13}$	$.7053 \times 10^{11}$	$.1626 \times 10^{12}$
	A	$.4002 \times 10^{13}$	$.2298 \times 10^{13}$	$.1468 \times 10^{13}$	$.7057 \times 10^{11}$	$.1640 \times 10^{12}$
	B	$.4202 \times 10^{13}$	$.2392 \times 10^{13}$	$.1438 \times 10^{13}$	$.2094 \times 10^{12}$	$.1617 \times 10^{12}$
	C	$.4054 \times 10^{13}$	$.2211 \times 10^{13}$	$.1456 \times 10^{13}$	$.2271 \times 10^{12}$	$.1605 \times 10^{12}$
	A'	$.4266 \times 10^{13}$	$.2573 \times 10^{13}$	$.1459 \times 10^{13}$	$.7151 \times 10^{11}$	$.1628 \times 10^{12}$
	B'	$.4362 \times 10^{13}$	$.2633 \times 10^{13}$	$.1451 \times 10^{13}$	$.1159 \times 10^{12}$	$.1624 \times 10^{12}$
	C'	$.40743 \times 10^{12}$	$.24093 \times 10^{12}$	$.12674 \times 10^{12}$	$.23861 \times 10^{11}$	$.15901 \times 10^{11}$
1991	Base	$.4409 \times 10^{13}$	$.2452 \times 10^{13}$	$.1735 \times 10^{13}$	$.7147 \times 10^{11}$	$.1501 \times 10^{12}$
	A	$.4257 \times 10^{13}$	$.2161 \times 10^{13}$	$.1863 \times 10^{13}$	$.7614 \times 10^{11}$	$.1572 \times 10^{12}$
	B	$.4665 \times 10^{13}$	$.2503 \times 10^{13}$	$.1720 \times 10^{13}$	$.2920 \times 10^{12}$	$.1495 \times 10^{12}$
	C	$.4286 \times 10^{13}$	$.2042 \times 10^{13}$	$.1763 \times 10^{13}$	$.3311 \times 10^{12}$	$.1508 \times 10^{12}$
	A'	$.4355 \times 10^{13}$	$.2437 \times 10^{13}$	$.1687 \times 10^{13}$	$.7669 \times 10^{11}$	$.1538 \times 10^{12}$
	B'	$.4450 \times 10^{13}$	$.2423 \times 10^{13}$	$.1729 \times 10^{13}$	$.1482 \times 10^{12}$	$.1501 \times 10^{12}$
	C'	$.43621 \times 10^{12}$	$.22112 \times 10^{12}$	$.16544 \times 10^{12}$	$.34469 \times 10^{11}$	$.15183 \times 10^{11}$

Table A4.34

Toronto-Windsor Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.1480 \times 10^{13}$	$.1130 \times 10^{13}$	$.1991 \times 10^{12}$	$.1322 \times 10^{12}$	$.1864 \times 10^{11}$
1986	Base	1.7628×10^{12}	$.1275 \times 10^{13}$	$.3577 \times 10^{12}$	1.1040×10^{11}	$.2023 \times 10^{11}$
	A	1.7243×10^{12}	$.1195 \times 10^{13}$	$.3906 \times 10^{12}$	1.1602×10^{11}	$.2258 \times 10^{11}$
	B	1.7799×10^{12}	$.1222 \times 10^{13}$	$.3433 \times 10^{12}$	1.9429×10^{11}	$.1989 \times 10^{11}$
	C	1.7375×10^{12}	$.1138 \times 10^{13}$	$.3742 \times 10^{12}$	2.0409×10^{11}	$.2124 \times 10^{11}$
	A'	1.7317×10^{12}	$.1250 \times 10^{13}$	$.3495 \times 10^{12}$	1.1158×10^{11}	$.2090 \times 10^{11}$
	B'	1.8091×10^{12}	$.1251 \times 10^{13}$	$.3536 \times 10^{12}$	1.8470×10^{11}	$.1989 \times 10^{11}$
	C'	1.6591×10^{12}	1.1442×10^{12}	2.8371×10^{11}	2.0958×10^{11}	2.1573×10^{10}
1991	Base	1.8593×10^{12}	$.1227 \times 10^{13}$	$.4633 \times 10^{12}$	1.4510×10^{11}	$.2385 \times 10^{11}$
	A	1.8083×10^{12}	$.1107 \times 10^{13}$	$.5218 \times 10^{12}$	1.5247×10^{11}	$.2685 \times 10^{11}$
	B	1.8779×10^{12}	$.1168 \times 10^{13}$	$.4371 \times 10^{12}$	2.5023×10^{11}	$.2236 \times 10^{11}$
	C	1.8256×10^{12}	$.1043 \times 10^{13}$	$.4895 \times 10^{12}$	2.6815×10^{11}	$.2474 \times 10^{11}$
	A'	1.8120×10^{12}	$.1220 \times 10^{13}$	$.4210 \times 10^{12}$	1.4482×10^{11}	$.2653 \times 10^{11}$
	B'	1.9225×10^{12}	$.1203 \times 10^{13}$	$.4533 \times 10^{12}$	2.4349×10^{11}	$.2295 \times 10^{11}$
	C'	1.7430×10^{12}	1.0641×10^{12}	3.8276×10^{11}	2.7046×10^{11}	2.5634×10^{10}

Table A4.35

Toronto-London Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.2161 \times 10^{13}$	$.1883 \times 10^{13}$	$.3130 \times 10^{11}$	$.2128 \times 10^{12}$	$.3410 \times 10^{11}$
1986	Base	2.6610×10^{12}	$.2297 \times 10^{13}$	$.4424 \times 10^{11}$	2.7517×10^{11}	$.4441 \times 10^{11}$
	A	2.5708×10^{12}	$.2183 \times 10^{13}$	$.5014 \times 10^{11}$	2.9093×10^{11}	$.4629 \times 10^{11}$
	B	2.7649×10^{12}	$.2206 \times 10^{13}$	$.4441 \times 10^{11}$	4.7587×10^{11}	$.4232 \times 10^{11}$
	C	2.6759×10^{12}	$.2083 \times 10^{13}$	$.4698 \times 10^{11}$	5.0209×10^{11}	$.4420 \times 10^{11}$
	A'	2.6118×10^{12}	$.2245 \times 10^{13}$	$.4326 \times 10^{11}$	2.7775×10^{11}	$.4545 \times 10^{11}$
	B'	2.7768×10^{12}	$.2258 \times 10^{13}$	$.4424 \times 10^{11}$	4.3026×10^{11}	$.4420 \times 10^{11}$
	C'	2.6676×10^{12}	2.0826×10^{12}	4.1108×10^{10}	4.9967×10^{11}	4.4200×10^{10}
1991	Base	2.7043×10^{12}	$.2250 \times 10^{13}$	$.6098 \times 10^{11}$	3.3992×10^{11}	$.5367 \times 10^{11}$
	A	2.5882×10^{12}	$.2077 \times 10^{13}$	$.6679 \times 10^{11}$	3.8751×10^{11}	$.5640 \times 10^{11}$
	B	2.9041×10^{12}	$.2148 \times 10^{13}$	$.5808 \times 10^{11}$	6.4718×10^{11}	$.5130 \times 10^{11}$
	C	2.7379×10^{12}	$.1967 \times 10^{13}$	$.6388 \times 10^{11}$	6.5407×10^{11}	$.5312 \times 10^{11}$
	A'	2.6865×10^{12}	$.2198 \times 10^{13}$	$.5711 \times 10^{11}$	3.6817×10^{11}	$.6349 \times 10^{11}$
	B'	2.8862×10^{12}	$.2208 \times 10^{13}$	$.6195 \times 10^{11}$	5.6337×10^{11}	$.5294 \times 10^{11}$
	C'	2.7232×10^{12}	1.9669×10^{12}	5.5172×10^{10}	6.4764×10^{11}	5.3487×10^{10}

Table A4.36

Toronto-Sudbury Total Energy (Btu)

Year	Scenario	Total	Automobile	CTOL	Rail	Bus
1976	Base	$.7811 \times 10^{12}$	$.4663 \times 10^{12}$	$.1797 \times 10^{12}$	$.7397 \times 10^{11}$	$.6112 \times 10^{11}$
1986	Base	$.1053 \times 10^{13}$	$.5218 \times 10^{12}$	$.3762 \times 10^{12}$	$.9197 \times 10^{11}$	$.6295 \times 10^{11}$
	A	$.1019 \times 10^{13}$	$.4773 \times 10^{12}$	$.3867 \times 10^{12}$	$.9157 \times 10^{11}$	$.6323 \times 10^{11}$
	A'	$.1028 \times 10^{13}$	$.5097 \times 10^{12}$	$.3635 \times 10^{12}$	$.9137 \times 10^{11}$	$.6315 \times 10^{11}$
	C'	9.3863×10^{11}	4.8408×10^{11}	2.9807×10^{11}	9.2903×10^{10}	6.3576×10^{10}
1991	Base	$.1117 \times 10^{13}$	$.4965 \times 10^{12}$	$.4712 \times 10^{12}$	$.9201 \times 10^{11}$	$.5754 \times 10^{11}$
	A	$.1068 \times 10^{13}$	$.4324 \times 10^{12}$	$.4857 \times 10^{12}$	$.9166 \times 10^{11}$	$.5809 \times 10^{11}$
	A'	$.1082 \times 10^{13}$	$.4965 \times 10^{12}$	$.4340 \times 10^{12}$	$.9287 \times 10^{11}$	$.5805 \times 10^{11}$
	C'	9.9635×10^{11}	4.5304×10^{11}	3.9149×10^{11}	9.3167×10^{10}	5.8651×10^{10}

Table A4.37
Total Energy Consumption (Btu) System Including Sudbury

Year	Scenario	All Modes ($\times 10^{13}$)	CTOL ($\times 10^{12}$)	Rail ($\times 10^{12}$)	Bus ($\times 10^{11}$)	Auto ($\times 10^{13}$)
1976	Base	2.09404	4.4858	1.22902	7.2656	1.4499
1986	Base	2.46245	6.0981	1.07526	8.5109	1.6600
	A	2.36273	6.0690	1.11412	8.7620	1.5568
	B					
	C					
	A'	2.43113	5.9590	1.11996	8.6430	1.6368
	B'					
	C'	2.37629	5.3624	2.07188	8.6658	1.5462
1991	Base	2.53095	7.3035	1.25272	9.0826	1.5845
	A	2.42592	7.5878	1.35077	9.5064	1.4370
	B					
	C					
	A'	2.48217	6.8542	1.36989	10.0820	1.5590
	B'					
	C'	2.42918	6.5453	2.60196	9.4053	1.4204

Table A4.38

System Scenario Results Without Sudbury

Year	Scenario	Total Travellers	Average User Trip Cost (1976\$)	Average User Trip Time (Minutes)	Total Energy Consumption (Btu)	Average Btu Energy (Eff P.M.) Consumption
1976	Base	16933000	17.87	203.7	2.01595x10 ¹³	7171.26
1986	Base	23107000	18.07	202.7	2.35713x10 ¹³	6152.70
	A	22504000	21.53	202.8	2.26092x10 ¹³	6047.86
	B	23547000	17.90	197.9	2.38662x10 ¹³	6099.38
	C	23059000	21.21	197.5	2.29741x10 ¹³	5990.33
	A'	22886000	19.32	203.2	2.32833x10 ¹³	6133.88
	B'	23271000	18.46	197.6	2.40192x10 ¹³	6250.22
	C'	22930000	21.66	199.2	2.28244x10 ¹³	5992.37
1991	Base	27253000	18.19	202.5	2.41917x10 ¹³	5353.53
	A	26239000	23.71	202.7	2.31918x10 ¹³	5312.47
	B	28047000	17.98	197.4	2.50014x10 ¹³	5365.56
	C	27044000	23.22	196.7	2.34446x10 ¹³	5209.75
	A'	27450000	18.25	204.5	2.37403x10 ¹³	5225.89
	B'	27541000	18.63	197.4	2.47069x10 ¹³	5422.70
	C'	26866000	23.71	198.0	2.32955x10 ¹³	5229.21

Table A4.39

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	5.04074x10 ⁸		2.50801x10 ⁸		3.70326x10 ⁸		2.04181x10 ⁹		1.6701x10 ⁹	
Effective Passenger Miles	4.50895x10 ⁸		2.31453x10 ⁸		3.21506x10 ⁸		1.80729x10 ⁹		2.81115x10 ⁹	
Total Energy Btu	4.00723x10 ¹²	4.30610x10 ¹²	1.07976x10 ¹²	1.15505x10 ¹²	5.81600x10 ¹¹	6.65440x10 ¹¹	1.40330x10 ¹³	1.97018x10 ¹³	2.01595x10 ¹³	
Btu/Actual Passenger Mile	7949.69	8542.59	4305.25	4605.44	1570.51	1796.90	6872.82	6220.95	6365.47	
Btu/Effective Passenger Mile	8887.28	9550.12	4665.14	4990.43	1808.99	2069.76	7764.66	7008.45	7171.26	
Total Direct Energy	2.93683x10 ¹²	3.15230x10 ¹²	7.15570x10 ¹¹	7.66420x10 ¹¹	4.18141x10 ¹¹	4.75313x10 ¹¹	9.34470x10 ¹²	1.34153x10 ¹³	1.37387x10 ¹³	
Btu/Actual Passenger Mile	5826.19	6253.65	2853.14	3055.89	1129.12	1283.50	4576.67	4235.95	4338.07	
Btu/Effective Passenger Mile	6513.33	6991.21	3091.64	3311.34	1300.57	1478.40	5170.56	4772.78	4887.22	
Total Indirect Energy	1.07040x10 ¹²	1.15380x10 ¹²	3.64190x10 ¹¹	3.88630x10 ¹¹	1.63459x10 ¹¹	1.90127x10 ¹¹	4.68830x10 ¹²	6.28650x10 ¹²	6.42080x10 ¹²	
Btu/Actual Passenger Mile	2123.50	2288.95	1452.11	1549.56	441.39	513.40	2296.15	1985.00	2027.40	
Btu/Effective Passenger Mile	2373.95	2558.91	1573.49	1679.09	508.42	591.36	2594.10	2236.27	2284.05	

Base scenario without Sudbury 1976

Table A4.40

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	5 230636x10 ⁸		2 58861x10 ⁸		4 008260x10 ⁸		21 14110x10 ⁸		32 96860x10 ⁸	
Effective Passenger Miles	4 697950x10 ⁸		2 379630x10 ⁸		3 471260x10 ⁸		18 70290x10 ⁸		29 25180x10 ⁸	
Total Energy, Btu	4 16413x10 ¹²	4 48580x10 ¹²	1 15032x10 ¹²	1 22902x10 ¹²	6 35150x10 ¹¹	7 26560x10 ¹¹	1 44990x10 ¹³	2 04491x10 ¹³	2 09407x10 ¹³	
Btu/Actual Passenger Mile	7961.04	8576.01	4443.77	4747.80	1584.60	1812.66	6858.21	6202.60	6351.71	
Btu/Effective Passenger Mile	8863.72	9548.42	4834.03	5164.75	1829.74	2093.07	7752.27	6990.72	7158.77	
Total Direct Energy	3 04421x10 ¹²	3 27654x10 ¹²	7 62240x10 ¹¹	8 15400x10 ¹¹	4 57141x10 ¹¹	5 19433x10 ¹¹	9 65340x10 ¹²	1 39170x10 ¹³	1 42648x10 ¹³	
Btu/Actual Passenger Mile	5819.96	6264.13	2944.59	3149.95	1140.50	1295.91	4566.18	4221.29	4326.78	
Btu/Effective Passenger Mile	6479.87	6974.04	3203.19	3426.58	1316.93	1496.38	5161.45	4757.66	4876.55	
Total Indirect Energy	1 11992x10 ¹²	1 20926x10 ¹²	3 88080x10 ¹¹	4 13620x10 ¹¹	1 78009x10 ¹¹	2 07127x10 ¹¹	4 84560x10 ¹²	6 54210x10 ¹²	6 67590x10 ¹²	
Btu/Actual Passenger Mile	2141.08	2311.88	1499.18	1597.85	444.11	516.75	2292.03	1981.31	2024.93	
Btu/Effective Passenger Mile	2383.95	2574.02	1630.84	1738.17	512.81	596.69	2590.83	2233.06	2282.22	

Base Scenario 1976 With Sudbury

Table A4.41

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.63706x10 ⁸		3.33705x10 ⁸		5.28462x10 ⁸		2.69338x10 ⁹		4.31927x10 ⁹	
Effective Passenger Miles	6.84457x10 ⁸		3.07699x10 ⁸		4.56815x10 ⁸		2.38207x10 ⁹		3.83105x10 ⁹	
Total Energy, Btu	5.33138x10 ¹²	5.72190x10 ¹²	8.90411x10 ¹¹	9.83290x10 ¹¹	6.78009x10 ¹¹	7.88140x10 ¹¹	1.6078x10 ¹³	2.29774x10 ¹³	2.35713x10 ¹³	
Btu/Actual Passenger Mile	6980.93	7492.28	2668.26	2946.58	1282.99	1491.38	5969.45	5319.74	5457.24	
Btu/Effective Passenger Mile	7789.21	8359.77	2893.77	3195.62	1484.21	1725.29	6749.59	5997.68	6152.70	
Total Direct Energy	3.84763x10 ¹²	4.12261x10 ¹²	4.93218x10 ¹¹	5.53977x10 ¹¹	4.80584x10 ¹¹	5.53720x10 ¹¹	1.02875x10 ¹³	1.51094x10 ¹³	1.55174x10 ¹³	
Btu/Actual Passenger Mile	5038.10	5398.16	1478.01	1660.08	909.40	1047.80	3819.55	3498.14	3902.71	
Btu/Effective Passenger Mile	5621.14	6023.18	1602.92	1800.39	1052.03	1212.13	4318.72	3943.93	4050.56	
Total Indirect Energy	1.48375x10 ¹²	1.59929x10 ¹²	3.97193x10 ¹¹	4.29313x10 ¹¹	1.97425x10 ¹¹	2.34420x10 ¹¹	5.79050x10 ¹²	7.86800x10 ¹²	8.05340x10 ¹²	
Btu/Actual Passenger Mile	1942.83	2094.12	1190.25	1286.50	373.58	443.51	2149.90	1821.60	1864.53	
Btu/Effective Passenger Mile	2167.78	2336.58	1290.85	1395.24	432.18	513.16	2430.87	2053.75	2102.14	

Base scenario without Sudbury, 1986

Table A4.42

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	8.01264x10 ⁸		3.44105x10 ⁸		5.67962x10 ⁸		2.78665x10 ⁹		4.50000x10 ⁹	
Effective Passenger Miles	7.21837x10 ⁸		3.16099x10 ⁸		4.89995x10 ⁸		2.46334x10 ⁹		3.99128x10 ⁹	
Total Energy, Btu	5.66858x10 ¹²	6.09810x10 ¹²	9.78521x10 ¹¹	1.07526x10 ¹²	7.32279x10 ¹¹	8.51090x10 ¹¹	1.66000x10 ¹³	2.39793x10 ¹³	2.46245x10 ¹³	
Btu/Actual Passenger Mile	7074.55	7610.60	2843.67	3124.80	1289.31	1498.50	5956.97	5328.51	5472.11	
Btu/Effective Passenger Mile	7852.99	8448.03	3095.62	3401.66	1494.46	1736.94	6738.82	6007.67	6169.57	
Total Direct Energy	4.08483x10 ¹²	4.38801x10 ¹²	5.53438x10 ¹¹	6.16737x10 ¹¹	5.19724x10 ¹¹	5.98540x10 ¹¹	1.06190x10 ¹³	1.57775x10 ¹³	1.62224x10 ¹³	
Btu/Actual Passenger Mile	5097.98	5476.36	1608.34	1792.29	915.07	1053.84	3810.67	3506.11	3604.98	
Btu/Effective Passenger Mile	5658.94	6078.95	1750.84	1951.09	1060.67	1221.52	4310.81	3952.99	4064.46	
Total Indirect Energy	1.58375x10 ¹²	1.71009x10 ¹²	4.25083x10 ¹¹	4.59523x10 ¹¹	2.12555x10 ¹¹	2.52550x10 ¹¹	5.98100x10 ¹²	8.20080x10 ¹²	8.40210x10 ¹²	
Btu/Actual Passenger Mile	1976.56	2134.24	1235.33	1332.51	374.24	444.66	2146.30	1822.40	1867.13	
Btu/Effective Passenger Mile	2194.05	2369.08	1344.78	1450.57	433.79	515.41	2428.00	2054.68	2105.11	

Base scenario with Sudbury, 1986

Table A4.43

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.80240x10 ⁸		3.50306x10 ⁸		5.53546x10 ⁸		2.52725x10 ⁹		4.21137x10 ⁹	
Effective Passenger Miles	6.99618x10 ⁸		3.22927x10 ⁸		4.78823x10 ⁸		2.23699x10 ⁹		3.73838x10 ⁹	
Total Energy, Btu	5.27953x10 ¹²	5.68270x10 ¹²	9.24780x10 ¹¹	1.02255x10 ¹²	6.97565x10 ¹¹	8.12970x10 ¹¹	1.50910x10 ¹³	2.19934x10 ¹³	2.26092x10 ¹³	
Btu/Actual Passenger Mile	6766.55	7283.27	2639.92	2919.02	1260.18	1468.66	5971.31	5222.39	5368.61	
Btu/Effective Passenger Mile	7546.30	8122.58	2863.74	3166.51	1456.83	1697.85	6746.12	5883.14	6047.86	
Total Direct Energy	3.78303x10 ¹²	4.06692x10 ¹²	5.12787x10 ¹¹	5.76826x10 ¹¹	4.93848x10 ¹¹	5.70524x10 ¹¹	9.65582x10 ¹²	1.44455x10 ¹³	1.48701x10 ¹³	
Btu/Actual Passenger Mile	4848.55	5212.40	1463.83	1646.63	892.15	1030.67	3820.68	3430.12	3530.94	
Btu/Effective Passenger Mile	5407.28	5813.06	1587.93	1786.24	1031.38	1191.51	4316.43	3864.11	3977.69	
Total Indirect Energy	1.49650x10 ¹²	1.61578x10 ¹²	4.11993x10 ¹¹	4.45724x10 ¹¹	2.03717x10 ¹¹	2.42446x10 ¹¹	5.43518x10 ¹²	7.5479x10 ¹²	7.73910x10 ¹²	
Btu/Actual Passenger Mile	1918.00	2070.88	1176.09	1272.38	368.02	437.99	2150.63	1792.27	1837.67	
Btu/Effective Passenger Mile	2139.02	2309.52	1275.81	1380.26	425.45	506.34	2429.68	2019.03	2070.17	

Scenario A 1986 without Sudbury

Table A4.44

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	8.18853x10 ⁸		3.61226x10 ⁸		5.94796x10 ⁸		2.61256x10 ⁹		4.38747x10 ⁹	
Effective Passenger Miles	7.38048x10 ⁸		3.31747x10 ⁸		5.13473x10 ⁸		2.31133x10 ⁹		3.89462x10 ⁹	
Total Energy, Btu	5.62623x10 ¹²	6.06900x10 ¹²	1.01230x10 ¹²	1.11412x10 ¹²	7.51725x10 ¹¹	8.76200x10 ¹¹	1.55680x10 ¹³	2.29591x10 ¹³	2.36273x10 ¹³	
Btu/Actual Passenger Mile	6870.87	7411.59	2802.40	3084.27	1263.84	1473.11	5958.91	5232.88	5385.18	
Btu/Effective Passenger Mile	7623.12	8223.04	3051.42	3358.34	1464.00	1706.42	6735.52	5895.08	6066.65	
Total Direct Energy	4.02693x10 ¹²	4.33972x10 ¹²	5.72377x10 ¹¹	6.39076x10 ¹¹	5.32818x10 ¹¹	6.15444x10 ¹¹	9.95902x10 ¹²	1.50912x10 ¹³	1.55533x10 ¹³	
Btu/Actual Passenger Mile	4917.77	5299.75	1584.54	1769.19	895.80	1034.71	3811.98	3439.61	3544.94	
Btu/Effective Passenger Mile	5456.19	5880.00	1725.34	1926.40	1037.67	1198.59	4308.78	3874.88	3993.53	
Total Indirect Energy	1.59930x10 ¹²	1.72928x10 ¹²	4.39923x10 ¹¹	4.75044x10 ¹¹	2.18907x10 ¹¹	2.60756x10 ¹¹	5.60898x10 ¹²	7.86790x10 ¹²	8.07400x10 ¹²	
Btu/Actual Passenger Mile	1953.10	2111.83	1217.86	1315.09	368.04	438.40	2146.93	1793.27	1840.24	
Btu/Effective Passenger Mile	2166.93	2343.05	1326.08	1431.95	426.33	507.83	2426.73	2020.20	2073.12	

Scenario A 1986 with Sudbury

Table A4.45

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.19814x10 ⁸		5.61220x10 ⁸		5.13052x10 ⁸		2.61267x10 ⁹		4.40675x10 ⁹	
Effective Passenger Miles	6.45158x10 ⁸		5.12533x10 ⁸		4.43526x10 ⁸		2.31144x10 ⁹		3.91289x10 ⁹	
Total Energy, Btu	5.27214x10 ¹²	5.64520x10 ¹²	1.68881x10 ¹²	1.83956x10 ¹²	6.75298x10 ¹¹	7.82410x10 ¹¹	1.55990x10 ¹³	2.32352x10 ¹³	2.38662x10 ¹³	
Btu/Actual Passenger Mile	7324.31	7842.58	3009.18	3277.79	1316.24	1525.01	5970.52	5272.64	5415.83	
Btu/Effective Passenger Mile	8171.86	8750.10	3295.03	3589.15	1522.57	1764.07	6748.61	5938.12	6099.38	
Total Direct Energy	3.83453x10 ¹²	4.09470x10 ¹²	1.03958x10 ¹²	1.13979x10 ¹²	4.79334x10 ¹¹	5.50464x10 ¹¹	9.98028x10 ¹²	1.53337x10 ¹³	1.57653x10 ¹³	
Btu/Actual Passenger Mile	5327.11	5688.55	1852.36	2030.91	934.28	1072.92	3819.95	3479.59	3577.53	
Btu/Effective Passenger Mile	5943.55	6346.82	2028.32	2223.84	1080.73	1241.11	4317.78	3918.77	4029.07	
Total Indirect Energy	1.43761x10 ¹²	1.55050x10 ¹²	6.49230x10 ¹¹	6.99770x10 ¹¹	1.95964x10 ¹¹	2.31945x10 ¹¹	5.61872x10 ¹²	7.90150x10 ¹²	8.10090x10 ¹²	
Btu/Actual Passenger Mile	1997.20	2154.03	1156.82	1246.87	381.96	452.09	2150.57	1793.04	1838.29	
Btu/Effective Passenger Mile	2228.31	2403.29	1266.71	1365.32	441.83	522.96	2430.83	2019.35	2070.31	

Scenario B, 1986

Table A4.46

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.33737x10 ⁸		5.87723x10 ⁸		5.39222x10 ⁸		2.45598x10 ⁹		4.31661x10 ⁹	
Effective Passenger Miles	6.57862x10 ⁸		5.36532x10 ⁸		4.66429x10 ⁸		2.17435x10 ⁹		3.83520x10 ⁹	
Total Energy, Btu	5.22135x10 ¹²	5.60100x10 ¹²	1.73950x10 ¹²	1.89798x10 ¹²	6.91559x10 ¹¹	8.04140x10 ¹¹	1.46710x10 ¹³		2.23231x10 ¹³	2.29741x10 ¹³
Btu/Actual Passenger Mile	7116.11	7633.53	2959.73	3229.38	1282.51	1491.30	5973.58		5171.44	5322.26
Btu/Effective Passenger Mile	7936.85	8513.93	3242.12	3537.50	1482.67	1724.04	6747.30		5820.58	5990.33
Total Direct Energy	3.77345x10 ¹²	4.04041x10 ¹²	1.06912x10 ¹²	1.17438x10 ¹²	4.89962x10 ¹¹	5.64739x10 ¹¹	9.38781x10 ¹²		1.47204x10 ¹³	1.51672x10 ¹³
Btu/Actual Passenger Mile	5142.78	5506.62	1819.09	1998.19	908.65	1047.32	3822.43		3410.18	3513.68
Btu/Effective Passenger Mile	5735.93	6141.73	1992.65	2188.83	1050.45	1210.77	4317.52		3838.24	3954.74
Total Indirect Energy	1.4479x10 ¹²	1.56059x10 ¹²	6.70380x10 ¹¹	7.23600x10 ¹¹	2.01597x10 ¹¹	2.39401x10 ¹¹	5.28319x10 ¹²		7.60270x10 ¹²	7.80690x10 ¹²
Btu/Actual Passenger Mile	1973.32	2126.91	1140.64	1231.19	373.87	443.97	2151.15		1761.27	1808.57
Btu/Effective Passenger Mile	2200.92	2372.21	1249.47	1348.66	432.21	513.26	2429.78		1982.35	2035.59

Scenario C, 1986

Table A4.47

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.48679x10 ⁸		3.57318x10 ⁸		5.40864x10 ⁸		2.63126x10 ⁹		4.27816x10 ⁹	
Effective Passenger Miles	6.70713x10 ⁸		3.29650x10 ⁸		4.67734x10 ⁸		2.32774x10 ⁹		3.79585x10 ⁹	
Total Energy, Btu	5.20926x10 ¹²	5.59550x10 ¹²	9.30412x10 ¹¹	1.028959x10 ¹²	6.88363x10 ¹¹	8.01150x10 ¹¹	1.58580x10 ¹³	2.26860x10 ¹³	2.32833x10 ¹³	
Btu/Actual Passenger Mile	6957.94	7473.83	2603.88	2878.64	1272.71	1481.24	6026.77	5302.75	5442.36	
Btu/Effective Passenger Mile	7766.75	8342.61	2822.42	3120.25	1471.70	1712.83	6812.47	5976.53	6133.88	
Total Direct Energy	3.75315x10 ¹²	4.02515x10 ¹²	5.14953x10 ¹¹	5.79165x10 ¹¹	4.87597x10 ¹¹	5.62507x10 ¹¹	1.01462x10 ¹³	1.49019x10 ¹³	1.53130x10 ¹³	
Btu/Actual Passenger Mile	5013.03	5376.34	1441.16	1620.87	901.51	1040.02	3856.02	3483.25	3579.34	
Btu/Effective Passenger Mile	5595.76	6001.30	1562.12	1756.91	1042.47	1202.62	4358.73	3925.84	4034.14	
Total Indirect Energy	1.45641x10 ¹²	1.57035x10 ¹²	4.15459x10 ¹¹	4.49425x10 ¹¹	2.00766x10 ¹¹	3.86433x10 ¹¹	5.7118x10 ¹²	7.78410x10 ¹²	7.97030x10 ¹²	
Btu/Actual Passenger Mile	1944.91	2097.49	1162.72	1257.77	371.19	441.23	2170.75	1819.50	1863.02	
Btu/Effective Passenger Mile	2170.99	2341.31	1260.30	1363.34	429.23	510.21	2453.74	2050.69	2099.74	

Scenario A', 1986 without Sudbury

Table A4.48

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.84971x10 ⁸		3.67978x10 ⁸		5.51524x10 ⁸		2.72236x10 ⁹		4.45671x10 ⁹	
Effective Passenger Miles	7.06833x10 ⁸		3.29650x10 ⁸		5.01754x10 ⁸		2.40717x10 ⁹		3.95398x10 ⁹	
Total Energy, Btu	5.53506x10 ¹²	5.95900x10 ¹²	1.01782x10 ¹²	1.11996x10 ¹²	7.42603x10 ¹¹	8.64300x10 ¹¹	1.63680x10 ¹³	2.36632x10 ¹³	2.43113x10 ¹³	
Btu/Actual Passenger Mile	7051.29	7591.36	2765.98	3043.55	1346.46	1567.11	6012.43	5309.57	5454.99	
Btu/Effective Passenger Mile	7830.79	8430.56	3087.58	3397.42	1480.01	1722.56	6799.69	5984.65	6148.56	
Total Direct Energy	3.98230x10 ¹²	4.28165x10 ¹²	5.74533x10 ¹¹	6.41345x10 ¹¹	5.26667x10 ¹¹	6.07417x10 ¹¹	1.04700x10 ¹³	1.55535x10 ¹³	1.60004x10 ¹³	
Btu/Actual Passenger Mile	5073.18	5454.53	1561.32	1742.89	954.93	1101.34	3845.93	3489.91	3590.18	
Btu/Effective Passenger Mile	5634.00	6057.51	1742.86	1945.53	1049.65	1210.59	4349.51	3933.63	4046.66	
Total Indirect Energy	1.55276x10 ¹²	1.67735x10 ¹²	4.43287x10 ¹¹	4.78615x10 ¹¹	2.15936x10 ¹¹	2.56883x10 ¹¹	5.89800x10 ¹²	8.10970x10 ¹²	8.31090x10 ¹²	
Btu/Actual Passenger Mile	1978.11	2136.83	1204.66	1300.66	391.53	465.77	2160.50	1819.66	1864.81	
Btu/Effective Passenger Mile	2196.78	2373.05	1344.72	1451.89	430.36	511.97	2450.18	2051.02	2101.91	

Scenario A', 1986 with Sudbury

Table A4.49

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	7.71918x10 ⁸		3.58147x10 ⁸		5.26676x10 ⁸		2.67811x10 ⁹		4.33495x10 ⁹	
Effective Passenger Miles	6.91838x10 ⁸		3.27890x10 ⁸		4.55293x10 ⁸		2.36792x10 ⁹		3.84294x10 ⁹	
Total Energy, Btu	5.38908x10 ¹²	5.78370x10 ¹²	1.20265x10 ¹²	1.30893x10 ¹²	6.76901x10 ¹¹	7.86590x10 ¹¹	1.61400x10 ¹³	2.34089x10 ¹³	2.40192x10 ¹³	
Btu/Actual Passenger Mile	6981.42	7492.64	3357.98	3654.73	1285.23	1493.50	6026.64	5400.04	5540.23	
Btu/Effective Passenger Mile	7789.51	8359.91	3667.85	3991.98	1486.74	1727.66	6816.11	6091.40	6250.22	
Total Direct Energy	3.89141x10 ¹²	4.16882x10 ¹²	7.50370x10 ¹¹	8.20020x10 ¹¹	4.79896x10 ¹¹	5.52752x10 ¹¹	1.03275x10 ¹³	1.54492x10 ¹³	1.58691x10 ¹³	
Btu/Actual Passenger Mile	5041.22	5400.60	2095.15	2289.62	911.18	1049.51	3856.26	3563.87	3660.73	
Btu/Effective Passenger Mile	5624.74	6025.72	2288.48	2500.90	1054.04	1214.06	4361.42	4020.15	4129.42	
Total Indirect Energy	1.49767x10 ¹²	1.61488x10 ¹²	4.52280x10 ¹¹	4.88910x10 ¹¹	1.97005x10 ¹¹	2.33838x10 ¹¹	5.81250x10 ¹²	7.95970x10 ¹²	8.15013x10 ¹²	
Btu/Actual Passenger Mile	1940.19	2092.04	1262.83	1365.11	374.05	443.99	2170.37	1836.17	1880.10	
Btu/Effective Passenger Mile	2164.77	2334.19	1379.37	1491.08	432.70	513.60	2454.69	2071.25	2120.81	

Scenario B', 1986

Table A4.50

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	6 36766x10 ⁸		6.20332x10 ⁸		5 47094x10 ⁸		2 46486x10 ⁹		4 28911x10 ⁹	
Effective Passenger Miles	5 70347x10 ⁸		5.66620x10 ⁸		4.73174x10 ⁸		2 19880x10 ⁹		3.80891x10 ⁹	
Total Energy, Btu	4 73760x10 ¹²	5.06440x10 ¹²	1.81232x10 ¹²	1.97898x10 ¹²	6 89264x10 ¹¹	8 03000x10 ¹¹	1 49780x10 ¹³	2.22167x10 ¹³	2.28244x10 ¹³	
Btu/Actual Passenger Mile	7440.10	7953.31	2921.53	3190.19	1259.86	1467.76	6027.70	5179.79	5321.47	
Btu/Effective Passenger Mile	8306.52	8879.51	3198.48	3492.61	1456.68	1697.05	6811.90	5832.82	5992.37	
Total Direct Energy	3.45757x10 ¹²	3.68759x10 ¹²	1.11460x10 ¹²	1.22349x10 ¹²	4.87925x10 ¹¹	5.63485x10 ¹¹	9.58376x10 ¹²	1.46438x10 ¹³	1.50582x10 ¹³	
Btu/Actual Passenger Mile	5429.89	5791.12	1796.78	1972.31	891.85	1029.96	3856.86	3414.18	3510.80	
Btu/Effective Passenger Mile	6062.22	6465.52	1967.10	2159.28	1031.17	1190.86	4358.63	3844.62	3953.41	
Total Indirect Energy	1.28003x10 ¹²	1.37681x10 ¹²	6.97720x10 ¹¹	7.55490x10 ¹¹	2.01339x10 ¹¹	2.39515x10 ¹¹	5 39424x10 ¹²	7.57290x10 ¹²	7.76618x10 ¹²	
Btu/Actual Passenger Mile	2010.24	2162.19	1124.75	1217.88	368.02	437.79	2170.84	1765.61	1810.67	
Btu/Effective Passenger Mile	2244.30	2413.99	1231.37	1333.33	425.51	506.19	2453.27	1988.21	2038.95	

Scenario C', 1986 ~~without~~ Sudbury

Table A4.51

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	6.663058x10 ⁸		6.315120x10 ⁸		5.890940x10 ⁸		2.571379x10 ⁹		4.458350x10 ⁹	
Effective Passenger Miles	5.997470x10 ⁸		5.756500x10 ⁸		5.084540x10 ⁸		2.274190x10 ⁹		3.958010x10 ⁹	
Total Energy, Btu	5.00503x10 ¹²	5.36240x10 ¹²	1.90107x10 ¹²	2.07188x10 ¹²	7.43604x10 ¹¹	8.66580x10 ¹¹	1.54620x10 ¹³	2.31113x10 ¹³	2.37629x10 ¹³	
Btu/Actual Passenger Mile	7511.61	8047.96	3010.35	3280.82	1262.28	1471.04	6013.12	5183.82	5239.98	
Btu/Effective Passenger Mile	8345.24	8941.10	3302.48	3599.20	1462.48	1704.34	6798.90	5839.12	6003.75	
Total Direct Energy	3.64412x10 ¹²	3.89632x10 ¹²	1.17482x10 ¹²	1.28644x10 ¹²	5.27001x10 ¹¹	6.08615x10 ¹¹	9.89127x10 ¹²	1.52372x10 ¹³	1.56825x10 ¹³	
Btu/Actual Passenger Mile	5469.14	5847.65	1860.33	2037.08	894.60	1033.14	3846.68	3417.68	3517.56	
Btu/Effective Passenger Mile	6076.10	6496.61	2040.86	2234.76	1036.48	1196.99	4349.36	3849.71	3982.22	
Total Indirect Energy	1.36091x10 ¹²	1.46608x10 ¹²	7.26250x10 ¹¹	7.85440x10 ¹¹	2.16603x10 ¹¹	2.57965x10 ¹¹	5.57073x10 ¹²	7.87410x10 ¹²	8.08040x10 ¹²	
Btu/Actual Passenger Mile	2042.47	2200.31	1150.02	1243.75	367.69	437.90	2166.44	1766.15	1812.42	
Btu/Effective Passenger Mile	2269.14	2444.50	1261.62	1364.44	426.00	507.35	2449.54	1989.41	2041.53	

Scenario C', 1986 with Sudbury

Table A4.52

Modal Energy Requirements, Efficiency and Productivity

	CTOL			Rail			Bus			Auto			Total System		
	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Total
Actual Passenger Miles	9.44400x10 ⁸		2.12095x10 ⁸			6.60332x10 ⁸			3.07577x10 ⁹			5.09257x10 ⁹			
Effective Passenger Miles	8.46741x10 ⁸		3.80058x10 ⁸			5.72047x10 ⁸			2.71985x10 ⁹			4.51883x10 ⁹			
Total Energy, Btu	6.47744x10 ¹²	6.83230x10 ¹²	1.07182x10 ¹²	7.41680x10 ¹¹	8.50720x10 ¹¹	1.53480x10 ¹³			4.989.97			4.641.78			
Btu/Actual Passenger Mile	6858.79	7234.54	2600.91	1123.19	1288.32	5642.96			5231.13			5353.53			
Btu/Effective Passenger Mile	7649.85	8068.94	2818.67	1296.54	1487.15	5642.96			5231.13			5353.53			
Total Direct Energy	4.65531x10 ¹²	4.88724x10 ¹²	5.89902x10 ¹¹	5.11321x10 ¹¹	5.78285x10 ¹¹	9.22671x10 ¹²			1.49833x10 ¹³			1.53349x10 ¹³			
Btu/Actual Passenger Mile	4929.38	5174.97	1431.47	774.34	875.75	2999.80			2942.19			3011.23			
Btu/Effective Passenger Mile	5497.91	5771.82	1551.32	893.84	1010.90	3392.36			3315.75			3393.56			
Total Indirect Energy	1.82213x10 ¹²	1.94506x10 ¹²	4.81918x10 ¹¹	2.30359x10 ¹¹	2.72435x10 ¹¹	6.12129x10 ¹²			8.65530x10 ¹²			8.85680x10 ¹²			
Btu/Actual Passenger Mile	1929.40	2059.57	1169.43	348.85	412.57	1990.17			1699.59			1739.16			
Btu/Effective Passenger Mile	2151.93	2297.11	1267.34	402.69	476.25	2250.60			1915.39			1959.98			

Base Scenario 1991 without Sudbury

Table A4.53

Modal Energy Requirements, Efficiency and Productivity

	CTOL			Rail			Bus			Auto			Total System		
	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Line-Haul	Line-Haul	Total	Total
Actual Passenger Miles	9.92508x10 ⁸			4.23795x10 ⁸			7.04582x10 ⁸			3.18036x10 ⁹			5.30122x10 ⁹		
Effective Passenger Miles	8.94621x10 ⁸			3.89708x10 ⁸			6.09217x10 ⁸			2.81099x10 ⁹			4.70447x10 ⁹		
Total Energy, Btu	6.91294x10 ¹²	7.30350x10 ¹²	1.16058x10 ¹²	1.25272x10 ¹²			7.91810x10 ¹¹	9.08260x10 ¹¹		1.58450x10 ¹³			2.47095x10 ¹³	2.53095x10 ¹³	
Btu/Actual Passenger Mile	6965.12	7358.63	2738.54	2955.96			1123.80	1289.08		4982.14			4661.10	4774.28	
Btu/Effective Passenger Mile	7727.23	8163.79	2978.08	3214.51			1299.72	1490.86		5636.80			5252.35	5379.88	
Total Direct Energy	4.95911x10 ¹²	5.21524x10 ¹²	6.50272x10 ¹¹	7.05071x10 ¹¹			5.46533x10 ¹¹	6.17925x10 ¹¹		9.52421x10 ¹²			1.56802x10 ¹³	1.60624x10 ¹³	
Btu/Actual Passenger Mile	4996.54	5254.61	1534.40	1663.71			775.68	877.01		2994.70			2957.85	3029.94	
Btu/Effective Passenger Mile	5543.25	5829.55	1668.61	1809.23			897.10	1014.29		3388.20			3333.04	3414.28	
Total Indirect Energy	1.95383x10 ¹²	2.08826x10 ¹²	5.10308x10 ¹¹	5.47649x10 ¹¹			2.45279x10 ¹¹	2.90335x10 ¹¹		6.32079x10 ¹²			9.02930x10 ¹²	9.24710x10 ¹²	
Btu/Actual Passenger Mile	1968.58	2104.02	1204.14	1292.25			348.12	412.07		1987.44			1703.25	1744.33	
Btu/Effective Passenger Mile	2183.98	2334.24	1309.46	1405.28			402.61	476.57		2248.60			1919.30	1965.60	

Base Scenario 1991 with Sudbury

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Table A4.54

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	9.7551x10 ⁸		4.4364x10 ⁸		7.0295x10 ⁸		2.7915x10 ⁹		4.9136x10 ⁹	
Effective Passenger Miles	8.7525x10 ⁸		4.0922x10 ⁸		6.0904x10 ⁸		2.4713x10 ⁹		4.3655x10 ⁹	
Total Energy, Btu	6.7327x10 ¹²	7.1021x10 ¹²	1.1631x10 ¹²	1.2591x10 ¹²	7.7691x10 ¹²	8.9255x10 ¹²	1.3938x10 ¹³	2.2611x10 ¹³	2.3191x10 ¹³	
Btu/Actual Passenger Mile	6901.78	7280.40	2621.87	2838.12	1105.22	1269.72	4992.98	4601.81	4719.91	
Btu/Effective Passenger Mile	8114.31	7692.33	2842.35	3076.79	1274.46	1464.15	5639.74	5179.54	5312.47	
Total Direct Energy	4.8343x10 ¹²	5.0757x10 ¹²	6.4526x10 ¹¹	7.0241x10 ¹¹	5.3509x10 ¹¹	6.0605x10 ¹¹	8.3802x10 ¹²	1.4394x10 ¹³	1.4764x10 ¹³	
Btu/Actual Passenger Mile	4955.66	5203.17	1454.46	1583.29	761.22	862.16	3002.02	2929.60	3004.82	
Btu/Effective Passenger Mile	5523.30	5799.15	1576.78	1716.44	877.78	994.18	3390.89	3297.39	3382.06	
Total Indirect Energy	1.8984x10 ¹²	2.0263x10 ¹²	5.1790x10 ¹¹	5.5665x10 ¹¹	2.4181x10 ¹¹	2.8649x10 ¹¹	5.5577x10 ¹²	8.4273x10 ¹²	8.4273x10 ¹²	
Btu/Actual Passenger Mile	1946.12	2077.23	1167.40	1254.83	344.00	407.56	1990.95	1672.21	1715.09	
Btu/Effective Passenger Mile	2169.03	2315.16	1265.58	1360.35	396.68	469.97	2248.85	1882.15	1930.41	

Scenario A, 1991 without Sudbury

Table A4.55
Modal Energy Requirements, Efficiency and Productivity

	Auto			Rail			Bus			Total System		
	Line-Haul	Total		Line-Haul	Total		Line-Haul	Total		Line-Haul	Total	
Actual Passenger Miles	1.0251x10 ⁹			4.5638x10 ⁸			7.5020x10 ⁸			2.8826x10 ⁹		
Effective Passenger Miles	9.2460x10 ⁸			4.1951x10 ⁸			6.4929x10 ⁸			2.5507x10 ⁹		
Total Energy, Btu	7.1816x10 ¹²	7.5878x10 ¹²		1.2512x10 ¹²	1.3507x10 ¹²		8.2709x10 ¹¹	9.5064x10 ¹¹		1.4370x10 ¹³	2.3631x10 ¹³	2.4259x10 ¹³
Btu/Actual Passenger Mile	7005.81	7402.01		2741.76	2959.74		1102.50	1267.18		4985.05	4620.61	4743.42
Btu/Effective Passenger Mile	7767.27	8206.52		2982.68	3219.81		1273.84	1464.11		5633.59	5200.22	5338.44
Total Direct Energy	5.1474x10 ¹²	5.4138x10 ¹²		7.0481x10 ¹¹	7.6407x10 ¹¹		5.7020x10 ¹¹	6.4590x10 ¹¹		8.6393x10 ¹²	1.5061x10 ¹³	1.5463x10 ¹³
Btu/Actual Passenger Mile	5021.36	5281.28		1544.34	1674.20		760.08	860.98		2997.03	2945.05	3023.53
Btu/Effective Passenger Mile	5567.13	5855.29		1680.05	1821.32		878.20	994.78		3386.94	3314.47	3402.81
Total Indirect Energy	2.0342x10 ¹²	2.1739x10 ¹²		5.4647x10 ¹¹	5.8669x10 ¹¹		2.5688x10 ¹¹	3.0473x10 ¹¹		5.7306x10 ¹²	8.5693x10 ¹²	8.7960x10 ¹²
Btu/Actual Passenger Mile	1984.45	2120.73		1197.42	1285.53		342.43	406.21		1988.01	1675.56	1719.89
Btu/Effective Passenger Mile	2200.14	2351.23		1302.64	1398.50		395.64	469.33		2246.65	1885.75	1935.63

Scenario A, 1991 with Sudbury

Table A4.56

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	8.90130x10 ⁸		7.20862x10 ⁸		6.44736x10 ⁸		2.99098x10 ⁹		5.24681x10 ⁹	
Effective Passenger Miles	7.98050x10 ⁸		6.57304x10 ⁸		5.58537x10 ⁸		2.64574x10 ⁹		4.65961x10 ⁹	
Total Energy, Btu	6.40274x10 ¹²	6.73760x10 ¹²	2.19662x10 ¹²	2.34501x10 ¹²	7.38126x10 ¹¹	8.44760x10 ¹¹	1.50740x10 ¹³	2.44110x10 ¹³	2.50014x10 ¹³	
Btu/Actual Passenger Mile	7193.04	7569.23	3047.21	3253.06	1144.85	1310.24	5039.82	4652.54	4765.07	
Btu/Effective Passenger Mile	8022.98	8442.58	3341.86	3567.62	1321.53	1512.85	5697.46	5238.85	5365.56	
Total Direct Energy :	4.63832x10 ¹²	4.85708x10 ¹²	1.35022x10 ¹²	1.44034x10 ¹²	5.09422x10 ¹¹	5.74935x10 ¹¹	9.06244x10 ¹²	1.55605x10 ¹³	1.59349x10 ¹³	
Btu/Actual Passenger Mile	5210.83	5456.60	1873.06	1998.08	790.12	891.74	3029.92	2965.71	3037.06	
Btu/Effective Passenger Mile	5812.07	6086.19	2054.18	2191.28	912.06	1029.36	3425.30	3339.44	3419.79	
Total Indirect Energy	1.76442x10 ¹²	1.88052x10 ¹²	8.46400x10 ¹¹	9.04670x10 ¹¹	2.28704x10 ¹¹	2.69825x10 ¹¹	6.01156x10 ¹²	8.85050x10 ¹²	9.06650x10 ¹²	
Btu/Actual Passenger Mile	1982.20	2112.64	1174.15	1254.98	354.73	418.50	2009.90	1686.83	1728.00	
Btu/Effective Passenger Mile	2210.91	2356.39	1287.68	1376.33	409.47	483.09	2212.17	1899.41	1945.76	

Scenario B, 1991

Table A4.57

Model Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	9.05165x10 ⁸		7.72656x10 ⁸		6.81914x10 ⁸		2.7017x10 ⁹		5.06089x10 ⁹	
Effective Passenger Miles	8.12242x10 ⁸		7.03507x10 ⁸		5.91495x10 ⁸		2.39294x10 ⁹		4.50014x10 ⁹	
Total Energy, Btu	6.30444x10 ¹²	6.64840x10 ¹²	2.27019x10 ¹²	2.42952x10 ¹²	7.65309x10 ¹¹	8.77660x10 ¹¹	1.34890x10 ¹³	2.28290x10 ¹³	2.34446x10 ¹³	
Btu/Actual Passenger Mile	6964.96	7344.96	2938.16	3144.37	1122.29	1287.05	4993.76	4510.87	4632.51	
Btu/Effective Passenger Mile	7761.78	8185.25	3226.96	3453.44	1293.86	1483.80	5637.00	5072.95	5209.75	
Total Direct Energy	4.52913x10 ¹²	4.75386x10 ¹²	1.38780x10 ¹²	1.48452x10 ¹²	5.27414x10 ¹¹	5.96390x10 ¹¹	8.10939x10 ¹²	1.45537x10 ¹³	1.49442x10 ¹³	
Btu/Actual Passenger Mile	5003.65	5251.93	1796.14	1921.32	773.43	874.58	3002.18	2875.72	2952.88	
Btu/Effective Passenger Mile	5576.08	5852.76	1972.69	2110.17	891.66	1008.28	3388.88	3234.05	3320.83	
Total Indirect Energy	1.77531x10 ¹²	1.89454x10 ¹²	8.82390x10 ¹¹	9.45000x10 ¹¹	2.37895x10 ¹¹	2.81270x10 ¹¹	5.37961x10 ¹²	8.27530x10 ¹²	8.50040x10 ¹²	
Btu/Actual Passenger Mile	1961.31	2093.03	1142.02	1223.05	348.86	412.47	1991.59	1635.15	1679.63	
Btu/Effective Passenger Mile	2185.69	2332.48	1254.27	1343.27	402.19	475.52	2248.12	1838.90	1888.92	

Scenario C, 1991

Table A4.58

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	8.84405x10 ⁸		4.66743x10 ⁸		7.41370x10 ⁸		3.02616x10 ⁹		5.11869x10 ⁹	
Effective Passenger Miles	7.92485x10 ⁸		4.30953x10 ⁸		6.43614x10 ⁸		2.67572x10 ⁹		4.54282x10 ⁹	
Total Energy, Btu	6.08775x10 ¹²	6.42020x10 ¹²	1.17788x10 ¹²	1.27702x10 ¹²	8.26685x10 ¹¹	9.50120x10 ¹¹	1.50930x10 ¹³		2.31846x10 ¹³	2.37403x10 ¹³
Btu/Actual Passenger Mile	6883.44	7259.34	2523.62	2736.02	1115.08	1281.57	4987.51		4529.40	4637.96
Btu/Effective Passenger Mile	7681.85	8101.35	2733.20	2963.25	1284.44	1476.23	5640.72		5103.57	5225.89
Total Direct Energy	4.37494x10 ¹²	4.59271x10 ¹²	6.47997x10 ¹¹	7.07021x10 ¹¹	5.69125x10 ¹¹	6.44897x10 ¹¹	9.07300x10 ¹²		1.46650x10 ¹³	1.50176x10 ¹³
Btu/Actual Passenger Mile	4946.76	5192.99	1388.34	1514.80	767.67	859.87	2998.29		2864.99	2933.88
Btu/Effective Passenger Mile	5520.53	5795.33	1503.64	1640.60	884.26	1001.99	3390.98		3228.17	3305.79
Total Indirect Energy	1.71281x10 ¹²	1.82749x10 ¹²	5.29883x10 ¹¹	5.69999x10 ¹¹	2.57560x10 ¹¹	3.05223x10 ¹¹	6.01970x10 ¹²		8.51960x10 ¹²	8.72270x10 ¹²
Btu/Actual Passenger Mile	1936.68	2066.35	1135.28	1221.23	347.41	411.70	1989.22		1664.41	1704.09
Btu/Effective Passenger Mile	2161.32	2306.02	1229.56	1322.65	400.18	474.23	2249.75		1875.40	1920.11

Scenario A' 1991 without Sudbury

Table A4.59

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	9.28715x10 ⁸		4.78963x10 ⁸		7.88120x10 ⁸		3.13075x10 ⁹		5.36656x10 ⁹	
Effective Passenger Miles	8.36585x10 ⁸		4.40823x10 ⁸		6.82884x10 ⁸		2.76686x10 ⁹		4.72720x10 ⁹	
Total Energy, Btu	6.48895x10 ¹²	6.85420x10 ¹²	1.26735x10 ¹²	1.36989x10 ¹²	8.76895x10 ¹¹	1.00820x10 ¹²	1.55900x10 ¹³	2.42220x10 ¹³	2.48217x10 ¹³	
Btu/Actual Passenger Mile	6987.02	7380.31	2646.03	2860.12	1112.64	1279.25	4979.64	4547.40	4659.99	
Btu/Effective Passenger Mile	7756.47	8193.07	2874.96	3107.57	1284.11	1476.39	5634.55	5123.96	5250.83	
Total Direct Energy	4.65484x10 ¹²	4.89481x10 ¹²	7.08797x10 ¹¹	7.69841x10 ¹¹	6.04285x10 ¹¹	6.84747x10 ¹¹	9.37050x10 ¹²	1.53384x10 ¹³	1.57199x10 ¹³	
Btu/Actual Passenger Mile	5012.13	5270.52	1479.86	1607.31	766.74	868.84	2993.05	2879.61	2951.23	
Btu/Effective Passenger Mile	5564.10	5850.94	1607.89	1746.37	884.90	1002.73	3386.69	3244.71	3325.41	
Total Indirect Energy	1.83411x10 ¹²	1.95939x10 ¹²	5.58553x10 ¹¹	6.00049x10 ¹¹	2.72610x10 ¹¹	3.23453x10 ¹¹	6.21950x10 ¹²	8.88360x10 ¹²	9.10180x10 ¹²	
Btu/Actual Passenger Mile	1974.89	2109.79	1166.17	1252.81	345.90	410.41	1986.58	1667.79	1708.76	
Btu/Effective Passenger Mile	2192.38	2352.13	1267.07	1361.20	399.20	473.66	2247.85	1879.25	1925.41	

Scenario A' 1991 with Sudbury

Table A4.60

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	9.54324x10 ⁸		4.57979x10 ⁸		6.60024x10 ⁸		3.06431x10 ⁹		5.13663x10 ⁹	
Effective Passenger Miles	8.55763x10 ⁸		4.18735x10 ⁸		5.71914x10 ⁸		2.70985x10 ⁹		4.55620x10 ⁹	
Total Energy, Btu	6.56095x10 ¹²	6.91710x10 ¹²	1.54583x10 ¹²	1.64885x10 ¹²	7.45416x10 ¹¹	8.53990x10 ¹¹	1.52870x10 ¹³	2.41390x10 ¹³	2.47069x10 ¹³	
Btu/Actual Passenger Mile	6874.97	7248.17	3375.33	3600.27	1129.38	1293.88	4988.73	4699.38	4809.94	
Btu/Effective Passenger Mile	7666.78	8082.96	3691.67	3937.69	1303.37	1493.21	5641.27	5298.06	5422.70	
Total Direct Energy	4.71947x10 ¹²	4.95177x10 ¹²	9.64450x10 ¹¹	1.02696x10 ¹²	5.14235x10 ¹¹	5.80864x10 ¹¹	9.19052x10 ¹²	1.53886x10 ¹³	1.57501x10 ¹³	
Btu/Actual Passenger Mile	4945.35	5188.77	2105.88	2242.37	779.12	880.06	2999.21	2995.85	3066.23	
Btu/Effective Passenger Mile	5514.93	5786.38	2303.25	2452.53	899.15	1015.65	3391.52	3377.51	3456.85	
Total Indirect Energy	1.84148x10 ¹²	1.96533x10 ¹²	5.81380x10 ¹¹	6.21890x10 ¹¹	2.31181x10 ¹¹	2.73126x10 ¹¹	6.09648x10 ¹²	8.75040x10 ¹²	8.95680x10 ¹²	
Btu/Actual Passenger Mile	1929.62	2059.39	1269.45	1357.90	350.26	413.81	1989.51	1703.53	1743.71	
Btu/Effective Passenger Mile	2151.86	2296.58	1388.42	1485.16	404.22	477.56	2249.75	1920.55	1965.85	

Scenario 8' 1991

Table A4.61

Modal Energy Requirements, Efficiency and Productivity

	CTOL			Rail			Bus			Auto			Total System		
	Line-Haul	Total		Line-Haul	Total		Line-Haul	Total		Line-Haul	Total		Line-Haul	Total	
Actual Passenger Miles	7.87832x10 ⁸			8.06010x10 ⁸			6.89596x10 ⁸			2.72883x10 ⁹			5.06360x10 ⁹		
Effective Passenger Miles	7.05785x10 ⁸			7.34159x10 ⁸			5.98138x10 ⁸			2.41678x10 ⁹			4.45488x10 ⁹		
Total Energy, Btu	5.85616x10 ¹²	6.15380x10 ¹²		2.34190x10 ¹²	2.50879x10 ¹²		7.68427x10 ¹¹	8.81880x10 ¹¹		1.37510x10 ¹³			2.27177x10 ¹³	2.32955x10 ¹³	
Btu/Actual Passenger Mile	7433.26	7811.06		2905.55	3112.60		1114.31	1278.84		5039.16			4486.47	4600.58	
Btu/Effective Passenger Mile	8297.37	8719.09		3189.91	3417.23		1284.70	1474.38		5689.80			5099.51	5229.21	
Total Direct Energy	4.26161x10 ¹²	4.45620x10 ¹²		1.43441x10 ¹²	1.53388x10 ¹²		5.29375x10 ¹¹	5.99034x10 ¹¹		8.26746x10 ¹²			1.44927x10 ¹³	1.48565x10 ¹³	
Btu/Actual Passenger Mile	5409.29	5658.28		1779.64	1903.05		767.66	868.67		3029.67			2862.13	2933.98	
Btu/Effective Passenger Mile	6038.11	6313.82		1953.81	2089.30		885.04	1001.50		3420.86			3253.22	3334.88	
Total Indirect Energy	1.59455x10 ¹²	1.69760x10 ¹²		9.07490x10 ¹¹	9.74910x10 ¹¹		2.39052x10 ¹¹	2.82846x10 ¹¹		5.48354x10 ¹²			8.22500x10 ¹²	8.43900x10 ¹²	
Btu/Actual Passenger Mile	2023.97	2154.77		1125.90	1209.55		346.66	410.16		2009.48			1624.34	1666.60	
Btu/Effective Passenger Mile	2259.26	2405.27		1236.09	1327.93		399.66	472.88		2268.94			1846.29	1894.33	

Scenario C' 1991 without Sudbury

Table A4.62

Modal Energy Requirements, Efficiency and Productivity

	CTOL		Rail		Bus		Auto		Total System	
	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total	Line-Haul	Total
Actual Passenger Miles	8.27078x10 ⁸		8.19530x10 ⁸		7.39096x10 ⁸		2.824266x10 ⁹		5.209950x10 ⁹	
Effective Passenger Miles	7.44845x10 ⁸		7.45079x10 ⁸		6.39718x10 ⁸		2.499940x10 ⁹		4.629600x10 ⁹	
Total Energy, Btu	6.21853x10 ¹²	6.54530x10 ¹²	2.43131x10 ¹²	2.60196x10 ¹²	8.18786x10 ¹¹	9.40530x10 ¹¹	1.42040x10 ¹³	2.36729x10 ¹³	2.42918x10 ¹³	
Btu/Actual Passenger Mile	7518.67	7913.76	2966.71	3174.94	1107.82	1272.54	5029.27	4543.79	4662.58	
Btu/Effective Passenger Mile	8348.76	8787.47	3263.16	3492.19	1279.92	1470.23	5681.74	5113.38	5247.06	
Total Direct Energy	4.50946x10 ¹²	4.72382x10 ¹²	1.49451x10 ¹²	1.59621x10 ¹²	5.64520x10 ¹¹	6.39142x10 ¹¹	8.53894x10 ¹²	1.51073x10 ¹³	1.54980x10 ¹³	
Btu/Actual Passenger Mile	5452.28	5711.46	1823.62	1947.71	763.80	864.76	3023.42	2899.70	2974.69	
Btu/Effective Passenger Mile	6054.23	6342.02	2005.84	2142.34	882.45	999.10	3415.66	3263.20	3347.59	
Total Indirect Energy	1.70907x10 ¹²	1.82148x10 ¹²	9.36800x10 ¹¹	1.00575x10 ¹²	2.54266x10 ¹¹	3.01388x10 ¹¹	5.66506x10 ¹²	8.56560x10 ¹²	8.79380x10 ¹²	
Btu/Actual Passenger Mile	2066.40	2202.31	1143.09	1227.23	344.02	407.78	2005.85	1644.08	1687.89	
Btu/Effective Passenger Mile	2294.53	2445.45	1257.32	1349.86	397.47	471.13	2266.08	1850.18	1899.47	

Scenario C' 1991 with Sudbury

Table A4.63

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	2.9887×10^{11}	7.5290×10^{10}	8.3840×10^{10}	4.5770×10^{11}
Access/Total Energy, %	6.9	6.5	12.6	2.3
Btu/Actual Intercity P.M.	592.91	300.19	226.39	144.52
Btu/Effective Intercity P.M.	662.84	325.29	260.77	162.81
Total Direct Access Energy, Btu	2.1547×10^{11}	5.0850×10^{10}	5.7172×10^{10}	3.2340×10^{11}
Direct Access/Total Access, %	72.1	67.5	68.2	70.7
Btu/Actual Intercity P.M.	427.46	202.75	154.38	102.12
Btu/Effective Intercity P.M.	477.88	219.70	177.83	115.04
Total Indirect Access Energy, Btu	8.3400×10^{10}	2.4440×10^{10}	2.6668×10^{10}	1.3430×10^{11}
Indirect Access/Total Access, %	27.9	32.5	31.8	29.3
Btu/Actual Intercity P.M.	165.45	97.45	72.01	42.40
Btu/Effective Intercity P.M.	184.96	105.60	82.94	47.78

P.M. = Passenger-Mile

Base Scenario, 1976
without Sudbury

Table A4.64

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.2167×10^{11}	7.8700×10^{10}	9.1410×10^{10}	4.9160×10^{11}
Access/Total Energy, %	7.2	6.4	12.6	2.3
Btu/Actual Intercity P.M.	614.97	304.03	228.06	149.11
Btu/Effective Intercity P.M.	684.70	330.72	263.33	168.05
Total Direct Access Energy, Btu	2.3233×10^{11}	5.3160×10^{10}	6.2292×10^{10}	3.4780×10^{11}
Direct Access/Total Access, %	72.2	67.5	68.1	70.7
Btu/Actual Intercity P.M.	444.17	205.36	155.41	105.49
Btu/Effective Intercity P.M.	494.17	223.39	179.45	118.89
Total Indirect Access Energy, Btu	8.9340×10^{10}	2.5540×10^{10}	2.9118×10^{10}	1.4380×10^{11}
Indirect Access/Total Access, %	27.8	32.5	31.9	29.3
Btu/Actual Intercity P.M.	170.80	98.67	72.64	43.62
Btu/Effective Intercity P.M.	190.17	107.33	83.88	49.16

P.M. = Passenger-Mile

Base Scenario, 1976
with Sudbury

Table A4.65

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.9052×10^{11}	9.2879×10^{10}	1.1013×10^{11}	5.9390×10^{11}
Access/Total Energy, %	6.8	9.4	14.0	2.5
Btu/Actual Intercity P.M.	511.35	278.32	208.39	137.50
Btu/Effective Intercity P.M.	570.56	301.85	241.08	155.02
Total Direct Access Energy, Btu	2.7498×10^{11}	6.0759×10^{10}	7.3136×10^{10}	4.0850×10^{11}
Direct Access/Total Access, %	70.4	65.4	66.4	68.8
Btu/Actual Intercity P.M.	360.06	182.07	138.40	94.57
Btu/Effective Intercity P.M.	402.04	197.47	160.10	106.63
Total Indirect Access Energy, Btu	1.1554×10^{11}	3.2120×10^{10}	3.6995×10^{10}	1.8540×10^{11}
Indirect Access/Total Access, %	29.6	34.6	33.6	31.2
Btu/Actual Intercity P.M.	151.29	96.25	70.01	42.93
Btu/Effective Intercity P.M.	168.80	104.39	80.98	48.39

P.M. = Passenger-Mile

Base Scenario, 1986
without Sudbury

Table A4.66

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	4.2952×10^{11}	9.6739×10^{10}	1.1881×10^{11}	6.4620×10^{11}
Access/Total Energy, %	7.0	9.0	14.0	2.6
Btu/Actual Intercity P.M.	536.05	281.11	209.19	143.60
Btu/Effective Intercity P.M.	595.04	306.04	242.48	161.90
Total Direct Access Energy, Btu	3.0318×10^{11}	6.3299×10^{10}	7.8816×10^{10}	4.4490×10^{11}
Direct Access/Total Access, %	70.6	65.4	66.3	68.8
Btu/Actual Intercity P.M.	378.38	183.95	138.77	98.87
Btu/Effective Intercity P.M.	420.01	200.25	160.85	111.47
Total Indirect Access Energy, Btu	1.2634×10^{11}	3.3440×10^{10}	3.9995×10^{10}	2.0130×10^{11}
Indirect Access/Total Access, %	29.4	34.6	33.7	31.2
Btu/Actual Intercity P.M.	157.68	97.18	70.42	44.73
Btu/Effective Intercity P.M.	175.03	105.79	81.62	50.43

P.M. = Passenger-Mile

Base Scenario, 1986
with Sudbury

Table A4.67

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	4.0317×10^{11}	9.7770×10^{10}	1.1541×10^{11}	6.1580×10^{11}
Access/Total Energy, %	7.1	9.6	14.2	2.7
Btu/Actual Intercity P.M.	516.72	279.10	208.48	146.22
Btu/Effective Intercity P.M.	576.28	302.77	241.02	164.72
Total Direct Access Energy, Btu	2.8389×10^{11}	6.4039×10^{10}	7.6676×10^{10}	4.2460×10^{11}
Direct Access/Total Access, %	70.4	65.5	66.4	69.0
Btu/Actual Intercity P.M.	363.85	182.80	138.52	100.82
Btu/Effective Intercity P.M.	405.78	198.31	160.13	113.58
Total Indirect Access Energy, Btu	1.1928×10^{11}	3.3731×10^{10}	3.8729×10^{10}	1.9120×10^{11}
Indirect Access/Total Access, %	29.6	34.5	33.6	31.0
Btu/Actual Intercity P.M.	152.88	96.29	69.97	45.40
Btu/Effective Intercity P.M.	170.50	104.45	80.89	51.14

P.M. = Passenger-Mile

Scenario A, 1986
without Sudbury

Table A4.68

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	4.427×10^{11}	1.0182×10^{11}	1.2448×10^{11}	6.6820×10^{11}
Access/Total Energy, %	7.3	9.1	14.2	2.8
Btu/Actual Intercity P.M.	540.72	281.87	209.27	152.30
Btu/Effective Intercity P.M.	599.92	306.92	242.42	171.57
Total Direct Access Energy, Btu	3.1279×10^{11}	6.6699×10^{10}	8.2626×10^{10}	4.6210×10^{11}
Direct Access/Total Access, %	70.6	65.5	66.4	69.2
Btu/Actual Intercity P.M.	381.98	184.65	138.91	105.33
Btu/Effective Intercity P.M.	423.81	201.06	160.92	118.65
Total Indirect Access Energy, Btu	1.2998×10^{11}	3.5121×10^{10}	4.1849×10^{10}	2.0610×10^{11}
Indirect Access/Total Access, %	29.4	34.5	33.6	30.8
Btu/Actual Intercity P.M.	158.73	97.23	70.36	46.97
Btu/Effective Intercity P.M.	176.12	105.87	81.50	52.92

P.M. = Passenger-Mile

Scenario A, 1986
with Sudbury

Table A4.69

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.7306×10^{11}	1.5075×10^{11}	1.0711×10^{11}	6.3100×10^{11}
Access/Total Energy, %	6.6	8.2	13.7	2.6
Btu/Actual Intercity P.M.	518.27	268.61	208.77	143.19
Btu/Effective Intercity P.M.	578.24	294.12	241.50	161.26
Total Direct Access Energy, Btu	2.6017×10^{11}	1.0021×10^{11}	7.1130×10^{10}	4.3160×10^{11}
Direct Access/Total Access, %	69.7	66.5	66.4	68.4
Btu/Actual Intercity P.M.	361.44	178.55	138.64	97.94
Btu/Effective Intercity P.M.	403.27	195.52	160.38	110.30
Total Indirect Access Energy, Btu	1.1289×10^{11}	5.0540×10^{11}	3.5982×10^{10}	1.9940×10^{11}
Indirect Access/Total Access, %	30.3	33.5	33.6	31.6
Btu/Actual Intercity P.M.	156.83	90.05	70.13	45.25
Btu/Effective Intercity P.M.	174.98	98.61	81.13	50.96

P.M. = Passenger-Mile

Scenario B, 1986

Table A4.70

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.7965×10^{11}	1.5848×10^{11}	1.1258×10^{11}	6.5100×10^{11}
Access/Total Energy, %	6.8	8.3	14.0	2.8
Btu/Actual Intercity P.M.	517.42	269.65	208.79	150.82
Btu/Effective Intercity P.M.	577.09	295.38	241.37	169.75
Total Direct Access Energy, Btu	2.6696×10^{11}	1.0526×10^{11}	7.4777×10^{10}	4.4680×10^{11}
Direct Access/Total Access, %	70.3	66.4	66.4	68.6
Btu/Actual Intercity P.M.	363.84	179.10	138.67	103.50
Btu/Effective Intercity P.M.	405.80	196.18	160.32	116.50
Total Indirect Access Energy, Btu	1.1269×10^{11}	5.3220×10^{10}	3.7804×10^{10}	2.0420×10^{11}
Indirect Access/Total Access, %	29.7	33.6	33.6	31.4
Btu/Actual Intercity P.M.	153.59	90.55	70.10	47.30
Btu/Effective Intercity P.M.	171.29	99.19	81.05	53.24

P.M. Passenger-Mile

Scenario C, 1986

Table A4.71

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.8624×10^{11}	9.8178×10^{10}	1.1279×10^{11}	5.9730×10^{11}
Access/Total Energy, %	6.9	9.5	14.1	2.6
Btu/Actual Intercity P.M.	515.89	274.76	208.53	139.61
Btu/Effective Intercity P.M.	575.86	297.83	241.13	157.35
Total Direct Access Energy, Btu	2.7200×10^{11}	6.4212×10^{10}	7.4910×10^{10}	4.1110×10^{11}
Direct Access/Total Access, %	70.4	65.4	66.4	68.8
Btu/Actual Intercity P.M.	363.31	179.71	138.51	96.09
Btu/Effective Intercity P.M.	405.54	194.79	160.15	108.30
Total Indirect Access Energy, Btu	1.1424×10^{11}	3.3966×10^{10}	3.7877×10^{10}	1.8620×10^{11}
Indirect Access/Total Access, %	29.6	34.6	33.6	31.2
Btu/Actual Intercity P.M.	152.58	95.05	70.04	43.52
Btu/Effective Intercity P.M.	170.32	103.04	80.98	49.05

P.M. = Passenger-Mile

Scenario A', 1986
without Sudbury

Table A4.72

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	4.2394×10^{11}	1.0214×10^{11}	1.2170×10^{11}	6.4810×10^{11}
Access/Total Energy, %	7.1	9.1	14.1	2.7
Btu/Actual Intercity P.M.	540.07	277.57	220.65	145.42
Btu/Effective Intercity P.M.	599.77	309.84	242.55	163.91
Total Direct Access Energy, Btu	2.9935×10^{11}	6.6812×10^{10}	8.0750×10^{10}	4.4690×10^{11}
Direct Access/Total Access, %	70.6	65.4	66.4	69.0
Btu/Actual Intercity P.M.	381.35	181.57	146.41	100.27
Btu/Effective Intercity P.M.	423.51	202.67	160.94	113.03
Total Indirect Access Energy, Btu	1.2459×10^{11}	3.5328×10^{10}	4.0947×10^{10}	2.0120×10^{11}
Indirect Access/Total Access, %	29.4	34.6	33.6	31.0
Btu/Actual Intercity P.M.	158.72	96.00	74.24	45.15
Btu/Effective Intercity P.M.	176.27	107.17	81.61	50.89

P.M. = Passenger-Mile

Scenario A', 1986
with Sudbury

Table A4.73

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.9462×10^{11}	1.0628×10^{11}	1.0969×10^{11}	6.1032×10^{11}
Access/Total Energy, %	6.8	8.1	13.9	2.5
Btu/Actual Intercity P.M.	511.22	296.75	208.27	140.79
Btu/Effective Intercity P.M.	570.40	324.13	240.92	158.82
Total Direct Access Energy, Btu	2.7741×10^{11}	6.9650×10^{10}	7.2856×10^{10}	4.1990×10^{11}
Direct Access/Total Access, %	70.3	65.5	66.4	68.8
Btu/Actual Intercity P.M.	359.38	194.47	138.33	96.86
Btu/Effective Intercity P.M.	400.98	212.42	160.02	109.27
Total Indirect Access Energy, Btu	1.1721×10^{11}	3.6630×10^{10}	3.6833×10^{10}	1.9043×10^{11}
Indirect Access/Total Access, %	29.7	34.5	33.6	31.2
Btu/Actual Intercity P.M.	151.85	102.28	69.94	43.93
Btu/Effective Intercity P.M.	169.42	111.71	80.90	49.56

P.M. = Passenger-Mile

Scenario B', 1986

Table A4.74

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.2680x10 ¹¹	1.6666x10 ¹¹	1.1374x10 ¹¹	6.0770x10 ¹¹
Access/Total Energy, %	6.5	8.4	14.2	2.7
Btu/Actual Intercity P.M.	513.21	268.60	207.90	141.68
Btu/Effective Intercity P.M.	572.99	294.13	240.37	159.55
Total Direct Access Energy, Btu	2.3002x10 ¹¹	1.0889x10 ¹¹	7.5560x10 ¹⁰	4.1440x10 ¹¹
Direct Access/Total Access, %	70.4	65.3	66.4	68.2
Btu/Actual Intercity P.M.	361.23	175.53	138.11	96.62
Btu/Effective Intercity P.M.	403.30	192.18	159.69	108.79
Total Indirect Access Energy, Btu	9.6780x10 ¹⁰	5.7770x10 ¹⁰	3.8176x10 ¹⁰	1.9328x10 ¹¹
Indirect Access/Total Access, %	29.6	34.7	33.6	31.8
Btu/Actual Intercity P.M.	151.95	93.13	69.77	45.06
Btu/Effective Intercity P.M.	169.69	101.96	80.68	50.74

P.M. = Passenger-Mile

Scenario C', 1986
without Sudbury

c
Table A4.75

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.5737×10^{11}	1.7081×10^{11}	1.2298×10^{11}	6.5160×10^{11}
Access/Total Energy, %	6.7	8.2	14.2	2.7
Btu/Actual Intercity P.M.	536.35	270.47	208.76	146.16
Btu/Effective Intercity P.M.	595.86	296.72	241.86	164.63
Total Direct Access Energy, Btu	2.5220×10^{11}	1.1162×10^{11}	8.1614×10^{10}	4.4530×10^{11}
Direct Access/Total Access, %	70.6	65.3	66.4	68.3
Btu/Actual Intercity P.M.	378.51	176.75	138.54	99.88
Btu/Effective Intercity P.M.	420.51	193.90	160.51	112.51
Total Indirect Access Energy, Btu	1.0517×10^{11}	5.9190×10^{10}	4.1362×10^{10}	2.0630×10^{11}
Indirect Access/Total Access, %	29.4	34.7	33.6	31.7
Btu/Actual Intercity P.M.	157.84	93.73	70.21	46.27
Btu/Effective Intercity P.M.	175.36	102.82	81.35	52.12

P.M. = Passenger-Mile

Scenario C', 1986
with Sudbury

Table A4.76

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.5490×10^{11}	8.8890×10^{10}	1.0904×10^{11}	5.5310×10^{11}
Access/Total Energy, %	5.2	7.7	12.8	2.3
Btu/Actual Intercity P.M.	375.75	215.70	165.13	108.61
Btu/Effective Intercity P.M.	419.09	233.76	190.61	122.40
Total Direct Access Energy, Btu	2.3193×10^{11}	5.2859×10^{10}	6.6964×10^{10}	3.5160×10^{11}
Direct Access/Total Access, %	65.4	59.5	61.4	63.6
Btu/Actual Intercity P.M.	245.59	128.27	101.41	69.04
Btu/Effective Intercity P.M.	273.91	139.01	117.06	77.81
Total Indirect Access Energy, Btu	1.2293×10^{11}	3.6031×10^{10}	4.2076×10^{10}	2.0150×10^{11}
Indirect Access/Total Access, %	34.6	40.5	38.6	36.4
Btu/Actual Intercity P.M.	130.17	87.44	63.72	39.57
Btu/Effective Intercity P.M.	145.18	94.76	73.88	45.59

P.M. = Passenger-Mile

Base Scenario, 1991
without Sudbury

Table A4.77

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.9056×10^{11}	9.2140×10^{10}	1.1645×10^{11}	6.0000×10^{11}
Access/Total Energy, %	5.3	7.4	12.8	2.4
Btu/Actual Intercity P.M.	393.51	217.42	165.28	113.18
Btu/Effective Intercity P.M.	436.56	236.43	191.14	127.53
Total Direct Access Energy, Btu	2.5613×10^{11}	5.4799×10^{10}	7.1394×10^{10}	3.8220×10^{11}
Direct Access/Total Access, %	65.6	59.5	61.3	63.7
Btu/Actual Intercity P.M.	258.07	129.31	101.33	72.09
Btu/Effective Intercity P.M.	286.30	140.62	117.19	81.24
Total Indirect Access Energy, Btu	1.3443×10^{11}	3.7341×10^{10}	4.5056×10^{10}	2.1780×10^{11}
Indirect Access/Total Access, %	34.4	40.5	38.7	36.3
Btu/Actual Intercity P.M.	135.44	88.11	63.95	41.08
Btu/Effective Intercity P.M.	150.26	95.82	73.96	46.30

P.M. = Passenger-Mile

Base Scenario, 1991
with Sudbury

Table A4.78

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.6934×10^{11}	9.5940×10^{10}	1.1563×10^{11}	5.8030×10^{11}
Access/Total Energy, %	5.2	7.6	13.0	2.5
Btu/Actual Intercity P.M.	378.62	216.25	164.50	118.10
Btu/Effective Intercity P.M.	421.98	234.44	189.69	132.93
Total Direct Access Energy, Btu	2.4144×10^{11}	5.7154×10^{10}	7.0956×10^{10}	3.6960×10^{11}
Direct Access/Total Access, %	65.4	59.6	61.4	63.7
Btu/Actual Intercity P.M.	247.51	128.83	100.94	75.22
Btu/Effective Intercity Btu	275.85	139.66	116.40	84.67
Total Indirect Access Energy, Btu	1.2790×10^{11}	3.8786×10^{10}	4.4677×10^{10}	2.1070×10^{11}
Indirect Access/Total Access, %	34.6	40.4	38.6	36.3
Btu/Actual Intercity P.M.	131.11	87.43	63.56	42.88
Btu/Effective Intercity P.M.	146.13	94.77	73.29	48.26

P.M. = Passenger-Mile

Scenario A, 1991
without Sudbury

Table A4.79

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	4.0614×10^{11}	9.9480×10^{10}	1.2354×10^{11}	6.2810×10^{11}
Access/Total Energy, %	5.4	7.4	13.0	2.6
Btu/Actual Intercity P.M.	396.20	217.98	164.68	122.81
Btu/Effective Intercity P.M.	439.25	237.13	190.27	138.22
Total Direct Access Energy, Btu	2.6644×10^{11}	5.9264×10^{11}	7.5696×10^{10}	4.0140×10^{11}
Direct Access/Total Access, %	65.6	59.6	61.3	63.9
Btu/Actual Intercity P.M.	259.92	129.86	100.90	78.48
Btu/Effective Intercity P.M.	288.16	141.27	116.58	88.34
Total Indirect Access Energy, Btu	1.3970×10^{11}	4.0216×10^{10}	4.7847×10^{10}	2.2670×10^{11}
Indirect Access/Total Access, %	34.4	40.4	38.7	36.1
Btu/Actual Intercity P.M.	136.28	88.11	63.78	44.33
Btu/Effective Intercity P.M.	151.09	95.86	73.69	49.88

P.M. = Passenger-Mile

Scenario A, 1991
with Sudbury

Table A4.80

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.3486×10^{11}	1.4839×10^{11}	1.0663×10^{11}	5.9040×10^{11}
Access/Total Energy, %	5.0	6.3	12.6	2.4
Btu/Actual Intercity P.M.	376.19	205.85	165.39	112.53
Btu/Effective Intercity P.M.	419.60	225.76	190.92	126.71
Total Direct Access Energy, Btu	2.1876×10^{11}	9.0120×10^{10}	6.5513×10^{10}	3.7440×10^{11}
Direct Access/Total Access, %	65.3	60.7	61.4	63.4
Btu/Actual Intercity P.M.	245.77	125.02	101.62	71.35
Btu/Effective Intercity P.M.	274.12	137.10	117.30	80.35
Total Indirect Access Energy, Btu	1.1610×10^{11}	5.8270×10^{10}	4.1121×10^{10}	2.1600×10^{11}
Indirect Access/Total Access, %	34.7	39.3	38.6	36.6
Btu/Actual Intercity P.M.	130.44	80.83	63.77	41.17
Btu/Effective Intercity P.M.	145.48	88.65	73.62	46.35

P.M. = Passenger-Mile

Scenario B, 1991

Table A4.81

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.4396×10^{11}	1.5933×10^{11}	1.1235×10^{11}	6.1560×10^{11}
Access/Total Energy, %	5.2	6.6	12.8	2.6
Btu/Actual Intercity P.M.	380.00	206.21	164.76	121.64
Btu/Effective Intercity P.M.	423.47	226.48	189.94	136.80
Total Direct Access Energy, Btu	2.2473×10^{11}	9.6720×10^{10}	6.8976×10^{10}	3.9050×10^{11}
Direct Access/Total Access, %	65.3	60.7	61.4	63.4
Btu/Actual Intercity P.M.	248.28	125.18	101.15	77.16
Btu/Effective Intercity P.M.	276.68	137.48	116.62	86.78
Total Indirect Access Energy, Btu	1.1923×10^{11}	6.2610×10^{10}	4.3375×10^{10}	2.2510×10^{11}
Indirect Access/Total Access, %	34.7	39.3	38.6	36.6
Btu/Actual Intercity P.M.	131.72	81.03	63.61	44.48
Btu/Effective Intercity P.M.	146.79	89.00	73.33	50.02

P.M. = Passenger-Mile

Scenario C, 1991

Table A4.82

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.3245×10^{11}	9.9140×10^{10}	1.2344×10^{11}	5.5570×10^{11}
Access/Total Energy, %	5.2	7.8	13.0	2.3
Btu/Actual Intercity P.M.	375.90	212.40	166.49	108.56
Btu/Effective Intercity P.M.	419.50	230.05	191.79	122.32
Total Direct Access Energy, Btu	2.1777×10^{11}	5.9024×10^{10}	7.5772×10^{10}	3.5260×10^{11}
Direct Access/Total Access, %	65.5	59.5	61.4	63.5
Btu/Actual Intercity P.M.	246.23	126.46	102.20	68.89
Btu/Effective Intercity P.M.	274.80	136.96	117.73	77.62
Total Indirect Access Energy, Btu	1.1468×10^{11}	4.0116×10^{10}	4.7663×10^{10}	2.0310×10^{11}
Indirect Access/Total Access, %	34.5	40.5	38.6	36.5
Btu/Actual Intercity P.M.	129.67	85.95	64.29	39.68
Btu/Effective Intercity P.M.	144.70	93.09	74.05	44.71

P.M. = Passenger-Mile

Scenario A', 1991
without Sudbury

Table A4.83

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.6525×10^{11}	1.0264×10^{11}	1.3131×10^{11}	5.9970×10^{11}
Access/Total Energy, %	5.3	7.5	13.0	2.6
Btu/Actual Intercity P.M.	393.29	214.09	166.61	112.59
Btu/Effective Intercity P.M.	436.60	232.61	192.28	126.87
Total Direct Access Energy, Btu	2.3997×10^{11}	6.1044×10^{10}	8.0462×10^{10}	3.8150×10^{11}
Direct Access/Total Access, %	65.7	59.5	61.3	63.6
Btu/Actual Intercity P.M.	258.39	127.45	102.10	71.62
Btu/Effective Intercity P.M.	286.84	138.48	117.83	80.70
Total Indirect Access Energy, Btu	1.2528×10^{11}	4.1496×10^{10}	5.0843×10^{10}	2.1820×10^{11}
Indirect Access/Total Access, %	34.3	40.5	38.7	36.4
Btu/Actual Intercity P.M.	134.90	86.64	64.51	40.97
Btu/Effective Intercity P.M.	149.75	94.13	74.46	46.16

P.M. = Passenger-Mile

Scenario A', 1991
with Sudbury

Table A4.84

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.5615×10^{11}	1.0302×10^{11}	1.0857×10^{11}	5.6790×10^{11}
Access/Total Energy, %	5.1	6.2	12.7	2.3
Btu/Actual Intercity P.M.	373.20	224.94	164.50	110.56
Btu/Effective Intercity P.M.	416.18	246.02	189.84	124.64
Total Direct Access Energy, Btu	2.3230×10^{11}	6.2510×10^{10}	6.6629×10^{10}	3.6150×10^{11}
Direct Access/Total Access, %	65.2	60.7	61.4	63.7
Btu/Actual Intercity P.M.	243.42	136.49	100.94	70.38
Btu/Effective Intercity P.M.	271.45	149.28	116.50	79.34
Total Indirect Access Energy, Btu	1.2385×10^{11}	4.0510×10^{10}	4.1945×10^{10}	2.0640×10^{11}
Indirect Access/Total Access, %	34.8	39.3	38.6	36.3
Btu/Actual Intercity P.M.	129.77	88.45	63.55	40.18
Btu/Effective Intercity P.M.	144.72	96.74	73.34	45.30

P.M. = Passenger-Mile

Scenario B', 1991

3 3

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A

Table A4.85

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	2.9764×10^{11}	1.6689×10^{11}	1.1345×10^{11}	5.7780×10^{11}
Access/Total Energy, %	4.8	6.7	12.9	2.5
Btu/Actual Intercity P.M.	377.80	207.05	164.53	114.11
Btu/Effective Intercity P.M.	421.72	227.32	189.68	129.70
Total Direct Access Energy, Btu	1.9459×10^{11}	9.9470×10^{10}	6.9659×10^{10}	3.6380×10^{11}
Direct Access/Total Access, %	65.4	59.6	61.4	63.0
Btu/Actual Intercity P.M.	246.99	123.41	101.01	71.85
Btu/Effective Intercity P.M.	275.71	135.49	116.46	81.66
Total Indirect Access Energy, Btu	1.0305×10^{11}	6.7430×10^{10}	4.3794×10^{10}	2.1400×10^{11}
Indirect Access/Total Access, %	34.6	40.4	38.6	37.0
Btu/Actual Intercity P.M.	130.80	83.65	63.50	42.26
Btu/Effective Intercity P.M.	146.01	91.84	73.22	48.04

P.M. = Passenger-Mile

Scenario C', 1991
without Sudbury

Table A4.86

Access Energy Requirements

	CTOL	Rail	Bus	Total
Total Access Energy, Btu	3.2677×10^{11}	1.7065×10^{11}	1.2174×10^{11}	6.1890×10^{11}
Access/Total Energy, %	5.0	6.6	12.9	2.5
Btu/Actual Intercity P.M.	395.02	208.23	164.72	118.79
Btu/Effective Intercity P.M.	438.71	229.03	190.31	133.68
Total Direct Access Energy, Btu	2.1436×10^{11}	1.0170×10^{11}	7.4622×10^{10}	3.9070×10^{11}
Direct Access/Total Access, %	65.6	59.6	61.3	63.1
Btu/Actual Intercity P.M.	259.18	124.09	100.96	74.99
Btu/Effective Intercity P.M.	287.79	136.50	116.65	84.39
Total Indirect Access Energy, Btu	1.1241×10^{11}	6.8950×10^{10}	4.7122×10^{10}	2.2820×10^{11}
Indirect Access/Total Access, %	34.4	40.4	38.7	36.9
Btu/Actual Intercity P.M.	135.91	84.14	63.76	43.81
Btu/Effective Intercity P.M.	150.92	92.54	73.66	49.29

P.M. = Passenger-Mile

Scenario C', 1991
with Sudbury

Table A5.1

System Modal Splits With Sudbury

(%)

Year	Scenario	CTOL	Rail	Bus	Auto
1976	Base	10.4	6.7	12.4	70.4
1986	Base	11.6	6.8	13.3	68.2
	A	12.3	7.3	14.3	66.0
	B				
	C				
	A'	11.6	7.3	13.8	67.4
	B'				
	C'	9.8	12.3	14.0	63.9
1991	Base	12.3	7.2	14.4	66.1
	A	13.4	8.0	15.8	62.8
	B				
	C				
	A'	11.5	7.9	16.2	64.4
	B'				
	C'	10.5	13.9	15.3	60.3

Table A5.2
Changes in Travel Demand, System With Sudbury

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
(%)						
1986	Base	36.6	52.3	37.5	46.9	32.3
	A	-2.6	3.0	5.2	4.6	-5.7
	B					
	C					
	A'	-1.0	-1.5	5.9	2.4	-2.2
	B'					
	C'	-1.0	-16.8	79.7	3.7	-7.2
1991	Base	61.0	89.8	71.2	86.5	51.2
	A	-3.7	4.4	7.9	6.0	-8.6
	B					
	C					
	A'	-0.7	-6.1	11.3	13.3	-2.0
	B'					
	C'	-1.6	-15.8	90.1	4.8	-10.2

Base scenarios relative to 1976 Base

Other scenarios relative to own-year Base

Table A5.3

Total Direct Energy Consumption System With Sudbury

(Btu)

Year	Scenario	All Modes ($\times 10^{13}$)	CTOL ($\times 10^{12}$)	Rail ($\times 10^{11}$)	Bus ($\times 10^{11}$)	Auto ($\times 10^{13}$)
1976	Base	1.42648	3.27654	8.15400	5.19433	0.96534
1986	Base	1.62224	4.38801	6.16737	5.98540	1.06190
	A	1.55533	4.33972	6.39076	6.15444	0.99590
	B					
	C					
	A'	1.60004	4.28165	6.41345	6.07417	1.04700
	B'					
	C'	1.56825	3.89632	12.86440	6.08615	0.98913
1991	Base	1.60624	5.21524	7.05071	6.17925	0.95242
	A	1.54632	5.41384	7.64075	6.45905	0.86393
	B					
	C					
	A'	1.57199	4.89481	7.69841	6.84747	0.93705
	B'					
	C'	1.54980	4.72382	15.96210	6.39142	0.85389

Table A5.4

Energy Conservation Potential Whole System Without Sudbury
Relative to Same-Year Base

Year	Scenario	Total Energy Saving (Increase) Btu x10 ¹¹	Percent Saving (Increase)	Direct Energy Saving (Increase) Btu x10 ¹¹	Percent Saving (Increase)	Indirect Energy Saving (Increase) Btu x10 ¹¹	Percent Saving (Increase)
1986	A	9.621	4.1	6.478	4.2	3.143	3.9
	B	(2.949)	(1.3)	(2.474)	(1.6)	(0.475)	(0.6)
	C	5.972	2.5	3.507	2.3	2.465	3.1
	A'	2.880	1.2	2.049	1.3	0.831	1.0
	B'	(4.479)	(1.9)	(3.512)	(2.3)	(0.967)	(1.2)
	C'	7.469	3.2	4.597	3.0	2.872	3.6
1991	A	9.999	4.1	5.704	3.7	4.295	4.8
	B	(8.097)	(3.3)	(6.000)	(3.9)	(2.097)	(2.4)
	C	7.471	3.1	3.907	2.5	3.564	4.0
	A'	4.514	1.9	3.173	2.1	1.341	1.5
	B'	(5.152)	(2.1)	(4.152)	(2.7)	(1.001)	(1.1)
	C'	8.962	3.7	4.784	3.1	4.178	4.7

Table A5.5

Energy Conservation Potential Whole System Without Sudbury

Relative to 1976 Base

Year	Scenario	Total Energy Increase Btu x10 ¹²	Percent Increase	Direct Energy Increase Btu x10 ¹²	Percent Increase	Indirect Energy Increase Btu x10 ¹²	Percent Increase
1986	Base	3.4118	16.9	1.7792	13.0	1.6326	25.4
	A	2.4497	12.2	1.1314	8.2	1.3183	20.5
	B	3.7067	18.4	2.0266	14.8	1.6801	26.2
	C	2.8146	14.0	1.4285	10.4	1.3861	21.6
	A'	3.1238	15.5	1.5743	11.5	1.5495	24.1
	B'	3.8597	19.1	2.1304	15.5	1.7293	26.9
	C'	2.6649	13.2	1.3195	9.6	1.3454	21.0
1991'	Base	4.0322	20.0	1.5962	11.6	2.4360	37.9
	A'	3.0323	15.0	1.0258	7.5	2.0065	31.3
	B	4.8419	24.0	2.1962	16.0	2.6457	41.2
	C	3.2851	16.3	1.2055	8.8	2.0796	32.4
	A'	3.5808	17.8	1.2789	9.3	2.3019	35.9
	B'	4.5474	22.6	2.0114	14.6	2.5360	39.5
	C'	3.1360	15.6	1.1178	8.1	2.0182	31.4

Table A5.6

Total Energy Rates, System Without Sudbury
(Btu/Effective Passenger-Mile)

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
1976	Base	7171.26	9550.12	4990.43	2069.76	7764.66
1986	Base	6152.70	8359.77	3195.62	1725.29	6749.59
	A	6047.86	8122.58	3166.51	1697.85	6746.12
	B	6099.38	8750.10	3589.15	1764.07	6748.61
	C	5990.33	8513.93	3537.50	1724.04	6747.30
	A'	6133.88	8342.61	3120.25	1712.83	6812.47
	B'	6250.22	8359.91	3991.98	1727.66	6816.11
	C'	5992.37	8879.51	3492.61	1697.05	6811.90
1991	Base	5353.53	8068.94	3052.43	1487.15	5642.96
	A	5312.47	8114.31	3076.79	1464.15	5639.74
	B	5365.56	8442.58	3567.62	1512.45	5697.46
	C	5209.75	8185.25	3453.44	1483.80	5637.00
	A'	5225.89	8101.35	2963.25	1476.23	5640.72
	B'	5422.70	8082.96	3937.69	1493.21	5641.27
	C'	5229.21	8719.09	3417.23	1474.38	5689.80

Table A5.7

Total Energy Rates, System With Sudbury
(Btu/Effective Passenger Mile)

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
1976	Base	7158.77	9548.42	5164.75	2093.07	7752.27
1986	Base	6169.57	8448.03	3401.66	1736.94	6738.82
	A	6066.65	8223.04	3358.34	1706.42	6735.52
	B					
	C					
	A'	6148.56	8430.56	3397.42	1722.56	6799.69
	B'					
	C'	6003.75	8941.10	3599.20	1704.34	6798.90
1991	Base	5379.88	8163.79	3214.51	1490.86	5636.80
	A	5338.44	8206.52	3219.81	1464.11	5633.59
	B					
	C					
	A'	5250.83	8193.07	3107.57	1476.39	5634.55
	B'					
	C'	5247.06	8787.47	3492.19	1470.23	5681.74

Table A5.8

Total Direct Energy Rates, System Without Sudbury
(Btu/Effective Passenger Mile)

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
1976	Base	4887.22	6991.21	3311.34	1478.40	5170.56
1986	Base	4050.56	6023.18	1800.39	1212.13	4318.72
	A	3977.69	5813.06	1786.24	1191.51	4316.43
	B	4029.07	6346.82	2223.84	1241.11	4317.78
	C	3954.74	6141.73	2188.83	1210.77	4317.52
	A'	4034.14	6001.30	1756.91	1202.62	4358.73
	B'	4129.42	6025.72	2500.90	1214.06	4361.42
	C'	3953.41	6465.52	2159.28	1190.86	4358.63
1991	Base	3393.56	5771.82	1690.33	1010.90	3392.36
	A	3382.06	5799.15	1716.44	994.18	3390.89
	B	3419.79	6086.19	2191.28	1029.36	3425.30
	C	3320.83	5852.76	2110.17	1008.28	3388.88
	A'	3305.79	5795.33	1640.60	1001.99	3390.98
	B'	3456.85	5786.38	2452.53	1015.65	3391.52
	C'	3334.88	6313.82	2089.30	1001.50	3420.86

Table A5.9

Total Direct Energy Rates, System With Sudbury
(Btu/Effective Passenger Mile)

Year	Scenario	All Modes	CTOL	Rail	Bus	Auto
1976	Base	4876.55	6974.04	3426.58	1496.38	5161.45
1986	Base	4064.46	6078.95	1951.09	1221.52	4310.81
	A	3993.53	5880.00	1926.40	1198.59	4308.78
	B					
	C					
	A'	4046.66	6057.51	1945.53	1210.59	4349.51
	B'					
	C'	3962.22	6496.61	2234.76	1196.99	4349.36
1991	Base	3414.28	5829.55	1809.23	1014.29	3388.20
	A	3402.81	5855.29	1821.32	994.78	3386.94
	B					
	C					
	A'	3325.41	5850.94	1746.37	1002.73	3386.69
	B'					
	C'	3347.59	6342.02	2142.34	999.10	3415.66

Table A5.10

Total Energy Rate Reductions, System Without Sudbury, Relative to 1976 Base

Year	Scenario	All Modes		CTOL		Rail		Bus		Auto	
		Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%
1986	Base	1018.56	14.2	1190.35	12.5	1794.81	36.0	344.47	16.6	1015.07	13.1
	A	1123.40	15.7	1427.54	14.9	1823.90	36.5	371.91	18.0	1018.54	13.1
	B	1071.88	14.9	800.02	8.4	1401.28	28.1	305.69	14.8	1016.05	13.1
	C	1180.93	16.5	1036.19	10.9	1452.93	29.1	345.72	16.7	1017.36	13.1
	A'	1037.38	14.5	1207.51	12.6	1870.18	37.5	356.93	17.2	952.19	12.2
	B'	921.04	12.8	1190.21	12.5	998.45	20.0	342.10	16.5	948.55	12.2
1991	C'	1178.89	16.4	670.61	7.0	1497.82	30.0	372.71	18.0	952.76	12.3
	Base	1817.73	25.3	1481.18	15.5	1938.00	38.8	582.61	28.1	2121.70	27.3
	A	1858.79	25.9	1435.81	15.0	1913.64	38.3	605.61	29.3	2124.92	27.4
	B	1805.70	25.2	1107.54	11.6	1422.81	28.5	557.31	26.9	2067.20	26.6
	C	1961.51	27.4	1364.87	14.3	1536.99	30.8	585.96	28.3	2127.66	27.4
	A'	1945.37	27.1	1448.77	15.2	2027.18	40.6	593.53	28.7	2123.94	27.4
	B'	1748.56	24.4	1467.16	15.4	1052.74	21.1	576.55	27.9	2123.39	27.3
	C'	1942.05	27.1	831.03	8.7	1573.20	31.5	595.38	28.8	2074.86	26.7

Total Energy rates incl. access/egress
Passenger miles are effective P.M.

Table A5.11

Total Energy Rate Changes, System Without Sudbury, Relative to Same-Year Base

Year	Scenario	All Modes		CTOL		Rail		Bus		Auto	
		Δ Btu/P.M.	%	Δ Btu/P.M.	%	Δ Btu/P.M.	%	Δ Btu/P.M.	%	Δ Btu/P.M.	%
1986	A	-104.84	-1.7	-237.19	-2.8	-29.11	-0.9	-27.44	-1.6	-3.47	-0.1
	B	-53.32	-0.9	390.33	4.7	393.53	12.3	38.78	2.2	-0.98	0
	C	-162.37	-2.6	154.16	1.8	341.88	10.7	-1.25	0	-2.29	0
	A'	-18.82	-0.3	-17.16	-0.2	-75.37	-2.4	-12.46	-0.7	62.88	0.9
	B'	97.52	1.6	0.14	0	796.36	24.9	2.37	0.1	66.52	1.0
	C'	-160.33	-2.6	519.74	6.2	296.99	9.3	-28.24	-1.6	62.31	1.0
1991	A	-41.06	-0.8	45.37	0.6	24.36	0.8	-23.00	-1.5	-3.22	-0.1
	B	12.03	0.2	373.64	4.6	515.19	16.9	25.30	1.7	54.50	1.0
	C	-143.78	-2.7	116.31	1.4	401.01	13.1	-3.35	-0.2	-5.96	-0.1
	A'	-127.64	-2.4	32.41	0.4	-89.18	-2.9	-10.92	-0.7	-2.24	0
	B'	69.17	1.3	14.02	0.2	885.26	29.0	6.06	0.4	-1.69	0
	C'	-124.32	-2.3	650.15	8.1	364.80	12.0	-12.77	-0.9	46.84	0.8

Total energy rates (incl. access/egress)
Passenger miles are effective P.M.

Table A5.12

Total Direct Energy Rate Reductions, System Without Sudbury, Relative to 1976 Base

Year	Scenario	All Modes		CTOL		Rail		Bus		Auto	
		Δ Btu/E.P.M. %	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%
1986	Base	836.66	17.1	968.03	13.8	1510.95	45.6	266.27	18.0	851.84	16.5
	A	909.53	18.6	1178.15	16.9	1525.10	46.1	286.89	19.4	854.13	16.5
	B	858.15	17.6	644.39	9.2	1087.50	32.8	237.29	16.1	852.78	16.5
	C	932.48	19.1	849.48	12.2	1122.51	33.9	267.63	18.1	853.04	16.5
	A'	853.08	17.5	989.91	14.2	1554.43	46.9	275.78	18.7	811.83	15.7
	B'	757.80	15.5	965.49	13.8	810.44	24.5	264.34	17.9	809.14	15.6
	C'	933.81	19.4	525.69	7.5	1152.06	34.8	287.54	19.4	811.93	15.7
1991	Base	1493.66	30.6	1219.39	17.4	1621.01	49.0	467.50	31.6	1778.20	34.4
	A	1505.16	30.8	1192.06	17.1	1594.90	48.2	484.22	32.8	1779.67	34.4
	B	1467.43	30.0	905.02	12.9	1120.06	33.8	449.04	30.4	1745.26	33.8
	C	1566.39	32.1	1138.45	16.3	1201.17	36.3	470.12	31.8	1781.68	34.5
	A'	1581.43	32.4	1195.88	17.1	1670.74	50.5	476.41	32.2	1779.58	34.4
	B'	1430.37	29.3	1204.83	17.2	858.81	25.9	462.75	31.3	1779.04	34.4
	C'	1552.34	31.8	677.39	9.7	1222.04	36.9	476.90	32.3	1749.70	33.8

Direct energy rates include access/egress
 Passenger miles are effective p.m.

Table A5.13

Total Direct Energy Rate Changes, System Without Sudbury, Relative to Same-Year Base

Year	Scenario	All Modes		CTOL		Rail		Bus		Auto	
		Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%	Δ Btu/E.P.M.	%
1986	A	-72.87	-1.8	-210.12	-3.5	-14.15	0.8	-20.62	-1.7	-2.29	-0.1
	B	-21.49	-0.5	323.64	5.4	423.45	23.5	28.98	2.4	-0.94	0
	C	-95.82	-2.4	118.55	2.0	388.44	21.6	-1.36	-0.1	-1.20	0
	A'	-16.42	-0.4	-21.88	-0.4	-43.48	2.4	-9.51	-0.8	40.01	0.9
	B'	78.86	1.9	2.54	0	700.51	38.9	1.93	0.2	42.70	1.0
	C'	-97.15	-2.4	442.34	7.3	358.89	19.9	-21.27	-1.8	39.91	0.9
1991	A	-11.5	-0.3	27.33	0.5	26.11	1.5	-16.72	-1.7	-1.47	0
	B	26.23	0.8	314.37	5.4	500.95	29.6	18.46	1.8	32.94	1.0
	C	-72.73	-2.1	80.94	1.4	419.84	24.8	-2.62	-0.3	-3.48	-0.1
	A'	-87.77	-2.6	23.51	0.4	-49.73	-2.9	-8.91	-0.9	-1.38	0
	B'	63.29	1.9	14.56	0.3	762.20	45.1	4.75	0.5	-0.84	0
	C'	-58.68	-1.7	542.00	9.4	398.97	23.6	-9.40	-0.9	28.50	0.8

Direct energy rates include access/egress
 Passenger miles are effective p.m.

Figure B.4

TOTAL LINK ACCESS ENERGY 1991					80 14 07	15:31:13
(BTU)						
SCENARIO C						
MONTREAL-OTTAWA/HULL						
ACCESS MODE: AUTO	BUS	METRO	TAXI/LIMO	TOTAL	INDIRECT	TOTAL
INTERCITY						
MODE						
CTOL	.3761E+10	.2329E+09	.4527E+07	.3433E+10	.2933E+10	.7431E+10
RAIL	.7100E+10	.1006E+10	.4091E+09	.4835E+10	.5231E+10	.1335E+11
BUS	.1614E+11	.6999E+10	.2238E+10	.1016E+11	.1347E+11	.3554E+11
STOL	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
TOTAL						
INDIRECT	.1076E+11	.2076E+10	.1454E+10	.7350E+10	.2164E+11	
TOTAL						
ENERGY	.2700E+11	.8238E+10	.2651E+10	.1843E+11		.5632E+11

DEMAND(4) Traffic per mode, order: auto, CTOL, rail, bus.

ICOUNT ICOUNT=1 where base year is being processed.
ICOUNT=2 when any future years are being processed.

RATIO Base year traffic ÷ total travel indicator.

RATIOM(4) Base year modal split ÷ modal split indicator.

CHECK , Number of modes whose load factors have converged to required limits.

BSYRLF(4) Saves base year load factors.

ERROR Accuracy to which load factors must approach desired load factors.

ITER , Maximum number of iterations for load factor calculation.

UPPLIM(4) Upper limits on load factors, order as for A.

ALOLIM(4) Lower limits on load factors, order as for A.

FREQH(4) Holds frequency values from base year.

UPTTEST Upper load factor test limit.

ALTEST Lower load factor test limit.

Figure B.1

ACCESS ENERGY REQUIREMENTS		1991	80	14	07	15131113
SCENARIO C						
MONTREAL-OTTAWA/HULL						
CYOL						
97000. PASS. PER YEAR						
ACCESS MODE:	AUTO	BUS	METRO	TAXI/LIMO	TOTAL	
MONTREAL						
TRAFFIC (X)	49.9	6.8	.2	42.2	99.1	
TRAFFIC (PASS./YR.)	48403.	6596.	194.	40934.	96127.	
ENERGY REQUIREMENTS (BTU)						
FUEL CONSUMPTION	.1212E+10	.1571E+09	.2045E+07	.1259E+10	.2630E+10	
ENERGY COST OF FUEL	.2363E+09	.1963E+08	.1360E+07	.2455E+09	.5028E+09	
VEHICLE CONSTRUCTION	.3183E+09	.1302E+08	.3129E+06	.3298E+09	.6614E+09	
VEHICLE MAINTENANCE	.1987E+09	.1865E+08	.2104E+06	.2059E+09	.4234E+09	
INFRASTRUCTURE 0 & M	.5361E+08	.3974E+07	.5989E+06	.5554E+08	.1137E+09	
INDIRECT ENERGY	.8069E+09	.5528E+08	.2482E+07	.8366E+09	.1701E+10	
TOTAL ENERGY	.2019E+10	.2123E+09	.4527E+07	.2096E+10	.4331E+10	
OTTAWA/HULL						
TRAFFIC (X)	49.8	1.3	.0	48.2	99.3	
TRAFFIC (PASS./YR.)	48306.	1261.	0.	46754.	94321.	
ENERGY REQUIREMENTS (BTU)						
FUEL CONSUMPTION	.1049E+10	.1533E+08	.0000E+00	.8038E+09	.1868E+10	
ENERGY COST OF FUEL	.2045E+09	.1932E+07	.0000E+00	.1568E+09	.3432E+09	
VEHICLE CONSTRUCTION	.2729E+09	.1198E+07	.0000E+00	.2100E+09	.4841E+09	
VEHICLE MAINTENANCE	.1704E+09	.1715E+07	.0000E+00	.1311E+09	.3031E+09	
INFRASTRUCTURE 0 & M	.4596E+08	.3656E+06	.0000E+00	.3537E+08	.8169E+08	
INDIRECT ENERGY	.6937E+09	.5210E+07	.0000E+00	.5332E+09	.1232E+10	
TOTAL ENERGY	.1740E+10	.2054E+08	.0000E+00	.1337E+10	.3100E+10	

Figure B.2

ACCESS ENERGY REQUIREMENTS					1991	80	14	07	15:31:13
SCENARIO C									
MONTREAL-OTTAWA/HULL									
RAIL									
417000. PASS. PER YEAR									
ACCESS MODEI	AUTO	BUS	METRO	TAXI/LIMO	TOTAL				
MONTREAL									
TRAFFIC (X)	24.0	9.6	11.2	34.6	79.4				
TRAFFIC (PASS./YR.)	10080.	40032.	46704.	144282.	331098.				
ENERGY REQUIREMENTS (BTU)									
FUEL CONSUMPTION	.1431E+10	.3839E+09	.1848E+09	.1330E+10	.3330E+10				
ENERGY COST OF FUEL	.2791E+09	.4798E+08	.1229E+09	.2594E+09	.7094E+09				
VEHICLE CONSTRUCTION	.3729E+09	.2947E+08	.2828E+08	.3473E+09	.7781E+09				
VEHICLE MAINTENANCE	.2328E+09	.4249E+08	.1902E+08	.2168E+09	.5110E+09				
INFRASTRUCTURE 0 & M	.4280E+08	.9055E+07	.5412E+08	.5848E+08	.1845E+09				
INDIRECT ENERGY	.9476E+09	.1292E+09	.2243E+09	.8819E+09	.2183E+10				
TOTAL ENERGY	.2379E+10	.5131E+09	.4091E+09	.2212E+10	.5513E+10				
OTTAWA/HULL									
TRAFFIC (X)	47.7	11.8	.0	38.6	98.1				
TRAFFIC (PASS./YR.)	198909.	49206.	0.	160962.	409077.				
ENERGY REQUIREMENTS (BTU)									
FUEL CONSUMPTION	.2842E+10	.3690E+09	.0000E+00	.1577E+10	.4788E+10				
ENERGY COST OF FUEL	.5542E+09	.4650E+08	.0000E+00	.3075E+09	.9081E+09				
VEHICLE CONSTRUCTION	.7391E+09	.2819E+08	.0000E+00	.1117E+09	.1179E+10				
VEHICLE MAINTENANCE	.4614E+09	.4037E+08	.0000E+00	.2570E+09	.7587E+09				
INFRASTRUCTURE 0 & M	.1245E+09	.8604E+07	.0000E+00	.6934E+08	.2024E+09				
INDIRECT ENERGY	.1879E+10	.1237E+09	.0000E+00	.1046E+10	.3048E+10				
TOTAL ENERGY	.4721E+10	.4977E+09	.0000E+00	.2623E+10	.7836E+10				

Figure B.3

ACCESS ENERGY REQUIREMENTS				1991	80 14 07	15:31113
SCENARIO C						
MONTREAL-OTTAWA/HULL						
BUS						
1515000. PASS. PER YEAR						
ACCESS MODE:	AUTO	BUS	METRO	TAXI/LIMO	TOTAL	
MONTREAL						
TRAFFIC (Z)	14.6	19.7	15.4	25.4		75.1
TRAFFIC (PASS./YR.)	221190.	298455.	233310.	384810.		1137765.
ENERGY REQUIREMENTS (BTU)						
FUEL CONSUMPTION	.3672E+10	.3090E+10	.1011E+10	.3759E+10		.1153E+11
ENERGY COST OF FUEL	.7159E+09	.3863E+09	.6721E+09	.7329E+09		.2507E+10
VEHICLE CONSTRUCTION	.9555E+09	.2422E+09	.1547E+09	.9804E+09		.2333E+10
VEHICLE MAINTENANCE	.5965E+09	.3468E+09	.1040E+09	.6120E+09		.1659E+10
INFRASTRUCTURE O & M	.1609E+09	.7391E+08	.2960E+09	.1651E+09		.6960E+09
INDIRECT ENERGY	.2429E+10	.1049E+10	.1227E+10	.2490E+10		.7195E+10
TOTAL ENERGY	.6100E+10	.4140E+10	.2238E+10	.6249E+10		.1873E+11
OTTAWA/HULL						
TRAFFIC (Z)	34.2	21.8	0.	26.4		82.4
TRAFFIC (PASS./YR.)	518130.	330270.	0.	399960.		1248360.
ENERGY REQUIREMENTS (BTU)						
FUEL CONSUMPTION	.6037E+10	.2146E+10	.0000E+00	.2347E+10		.1053E+11
ENERGY COST OF FUEL	.1177E+10	.2705E+09	.0000E+00	.4577E+09		.7984E+10
VEHICLE CONSTRUCTION	.1574E+10	.1618E+09	.0000E+00	.6162E+09		.2354E+10
VEHICLE MAINTENANCE	.9836E+09	.2317E+09	.0000E+00	.3847E+09		.1600E+10
INFRASTRUCTURE O & M	.2654E+09	.4938E+08	.0000E+00	.1038E+09		.4185E+09
INDIRECT ENERGY	.4002E+10	.7133E+09	.0000E+00	.1562E+10		.6278E+10
TOTAL ENERGY	.1004E+11	.2860E+10	.0000E+00	.3910E+10		.1481E+11

Figure B.4

TOTAL LINK ACCESS ENERGY 1991					80 14 07	15:31:13
(BTJ)						
SCENARIO C						
MONTREAL-OTTAWA/HULL						
ACCESS MODE: AUTO	BUS	METRO	TAXI/LIMO	TOTAL	INDIRECT	TOTAL
INTERCITY MODE						
CTOL	.3761E+10	.2329E+09	.4527E+07	.3433E+10	.2933E+10	.7431E+10
RAIL	.7100E+10	.1006E+10	.4091E+09	.4835E+10	.5231E+10	.1335E+11
BUS	.1614E+11	.6999E+10	.2238E+10	.1016E+11	.1347E+11	.3554E+11
STOL	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
TOTAL	.1076E+11	.2076E+10	.1454E+10	.7350E+10	.2164E+11	
INDIRECT						
TOTAL ENERGY	.2700E+11	.8238E+10	.2651E+10	.1843E+11		.5632E+11

Figure B.5

LINE-HAUL ENERGY 1991 (BTU)		SCENARIO C		MONTREAL-OTTAWA/HULL		RO 14 07 15:31:13	
LOAD FACTOR							
	CTOL	RAIL	BUS	AUTO	STOL	TOTAL	
	.642	.600	.700	.300	.000		
ANNUAL PASSENGERS	97000.	417000.	1515000.	3381000.	0.	5410000.	
FUEL CONSUMPTION							
	.1093E+12	.7304E+11	.1486E+12	.1375E+13	.0000E+00	.1705E+13	
ENERGY COST OF FUEL	.1377E+11	.9203E+10	.1872E+11	.2680E+12	.0000E+00	.3097E+12	
VEHICLE CONSTRUCTION	.8230E+09	.4192E+10	.8387E+10	.7909E+12	.0000E+00	.4043E+12	
VEHICLE MAINTENANCE	.1620E+10	.8384E+10	.2137E+11	.2440E+12	.0000E+00	.2753E+12	
INFRASTRUCTURE DEM	.3224E+11	.4553E+11	.2275E+11	.6717E+09	.0000E+00	.1012E+12	
TOTAL INDIRECT.							
	.4845E+11	.6731E+11	.7123E+11	.9036F+12	.0000E+00	.1091E+13	
TOTAL ENERGY							
	.1578E+12	.1404E+12	.2198E+12	.2278E+13	.0000E+00	.2796E+13	

Figure B.6

		TOTAL ENERGY 1991 (BTU)		80 14 07 15:31:13	
SCENARIO C					
MONTREAL-OTTAWA/HULL					
	CTOL	RAIL	BUS	AUTO	TOTAL
ANNUAL PASSENGERS	97000.	417000.	1515000.	3381000.	0. 5410000.
FUEL CONSUMPTION	.1138E+12	.8116E+11	.1706E+12	.1375E+13	.0000E+00 .1740E+13
ENERGY COST OF FUEL	.1464E+11	.1082E+11	.2313E+11	.2680E+12	.0000E+00 .3166E+12
VEHICLE CONSTRUCTION	.1969E+10	.6149E+10	.1307E+11	.3909E+12	.0000E+00 .4121E+12
VEHICLE MAINTENANCE	.2344E+10	.9654E+10	.2463E+11	.2440E+12	.0000E+00 .2806E+12
INFRASTRUCTURE O&M	.3243E+11	.4592E+11	.2387E+11	.6717E+09	.0000E+00 .1029E+12
TOTAL INDIRECT	.5139E+11	.7254E+11	.8470E+11	.9036E+12	.2817E+31 .1112E+13
TOTAL ENERGY	.1652E+12	.1537E+12	.2553E+12	.2278E+13	.0000E+00 .2852E+13

Figure B.7

SCENARIO C 1991

MODAL ENERGY REQUIREMENTS, EFFICIENCY AND PRODUCTIVITY

	AUTO			CTOL			RAIL			BUS			TOTAL	
	LINE-HAUL	LINE-HAUL	TOTAL	LINE-HAUL	LINE-HAUL	TOTAL	LINE-HAUL	LINE-HAUL	TOTAL	LINE-HAUL	LINE-HAUL	TOTAL	LINE-HAUL	TOTAL
PASSENGER MILES (ACTUAL)	4.1586E+08	1.2009E+07		4.8172E+07			1.8938E+08			4.6542E+08			4.6542E+08	
PASSENGER MILES (EFFECTIVE)	3.4486E+08	9.8940E+06		4.2534E+07			1.5453E+08			3.5182E+08			3.5182E+08	
TOTAL ENERGY, BTU	2.2780E+12	1.5780E+11	1.6520E+11	1.4091E+11	1.5421E+11	2.1980E+11	2.5510E+11	2.7945E+12	2.8527E+12					
BTU/PASSENGER MILE (ACTUAL)	5.4778E+03	1.3141E+04	1.3157E+04	2.9130E+03	3.1880E+03	1.1407E+03	1.3481E+03	4.2014E+03	4.2858E+03					
BTU/PASSENGER MILE (EFFECTIVE)	6.6055E+03	1.5949E+04	1.6697E+04	3.3129E+03	3.6256E+03	1.4224E+03	1.6521E+03	5.0678E+03	5.1696E+03					
TOTAL DIRECT ENERGY	1.3744E+12	1.0935E+11	1.1158E+11	7.3090E+10	8.1160E+10	1.4857E+11	1.7060E+11	1.7054E+12	1.7400E+12					
BTU/PASSENGER MILE (ACTUAL)	3.3049E+03	9.1060E+03	9.4774E+03	1.5110E+03	1.6778E+03	7.8453E+02	9.0084E+02	2.5621E+03	2.6141E+03					
BTU/PASSENGER MILE (EFFECTIVE)	3.9854E+03	1.1052E+04	1.1503E+04	1.7184E+03	1.9081E+03	9.6143E+02	1.1040E+03	3.0905E+03	3.1532E+03					
TOTAL INDIRECT ENERGY	9.0360E+11	4.8450E+10	5.1390E+10	6.7819E+10	7.3049E+10	7.1230E+10	8.4700E+10	1.0911E+12	1.1127E+12					
BTU/PASSENGER MILE (ACTUAL)	2.1728E+03	4.0346E+03	4.2794E+03	1.4020E+03	1.5107E+03	3.7613E+02	4.4726E+02	1.8392E+03	1.8717E+03					
BTU/PASSENGER MILE (EFFECTIVE)	2.6202E+03	4.8969E+03	5.1941E+03	1.5945E+03	1.7174E+03	4.6095E+02	5.4811E+02	1.9773E+03	2.0145E+03					
TRIP COST (\$)	5.1337E+07	2.9003E+06		5.5878E+04			2.0907E+07			8.0752E+07				
TRIP TIME (MINUTES)	4.9343E+08	1.2804E+07		5.9214E+07			3.7421E+08			8.8985E+08				
RAIL INFRA. CONST. ENERGY				5.0906E+08										

Appendix C

Demand Model Program

This program is written in FORTRAN77. The program listing and variable list explain the details of the program. Where lists of parameters occur, the order of modes used is: auto, CTOL, rail, bus. The subroutine GETTIME provides date and time information for the printout. It is a Carleton University computer system library routine and can be eliminated from the program.

The section on the demand model formulation provides details on the use of the program.

Demand program variables

TRAFIK	Base year total traffic.
AMS(4)	Base year modal split in order: auto, CTOL, rail, bus in %.
NAME(13)	Name of link, for printout, 52 characters.
COST(4)	Trip cost, in cents, in order auto, CTOL, rail, bus.
TIME(4)	Trip time, in minutes, same order.
FREQ(4)	Annual frequency, same order.
SEAT(4)	Vehicle size, in seats, same order.
POP1, POP2	City populations of city pair, order is not significant.
Y1, Y2	City average annual per capita disposable income, in dollars. Order must match population input.
PL	Language pairing index, $0 < PL \leq 1.0$
A(4)	Coefficients for demand model, order: auto, CTOL, rail, bus. See demand model description.
UMODE(4)	Composite level of service, order as for A.
PMODE(4)	Modal split indicator, order as for A.
SIGU	System level of service measure. The sum of UMODEs.
YAVG	Average annual per capital disposable income.
TOTAL	Total travel indicator.
AMSSUM	Sum of modal splits, used for normalization.
TLCOST(5)	Sum of all user costs per mode, in order auto, CTOL, rail, bus, total all modes.
TLTIME(5)	Sum of all user trip time, per mode, order as for TLCOST.
TLSEAT(5)	Sum of all seats provided, per mode order as for TLCOST.

DEMAND(4) Traffic per mode, order: auto, CTOL, rail, bus. 、
ICOUNT ICOUNT=1 where base year is being processed.
ICOUNT=2 when any future years are being processed.
RATIO Base year traffic ÷ total travel indicator.
RATIOM(4) Base year modal split ÷ modal split indicator.
CHECK , Number of modes whose load factors have converged to
required limits.
BSYRLF(4) Saves base year load factors.
ERROR Accuracy to which load factors must approach desired
load factors.
ITER , Maximum number of iterations for load factor calculation.
UPPLIM(4) Upper limits on load factors, order as for A.
ALOLIM(4) Lower limits on load factors, order as for A.
FREQH(4) Holds frequency values from base year.
UPTTEST Upper load factor test limit.
ALTEST Lower load factor test limit.

Energy calculator program variables

<u>VARIABLE NAME (DIMENSION)</u>	<u>DEFINITION</u>
LINK	One digit from 1 to 7 to identify link being calculated, used to select link energy data.
YEAR	Year of demand data, four digits, used to check that year of energy data matches, also used in printouts.
SCENARIO	Name of scenario being calculated, 40 alphanumeric characters, used in printout.
VOL(5)	Modal volumes, in order, CTOL, rail, bus, auto, STOL.
XLFF(5)	Modal load factors, %, in order: CTOL, rail, bus, auto, STOL.
COST(5)	Modal trip cost, per user, in cents, in order: CTOL, rail, bus, auto, STOL.
TTIME(5)	Modal trip time, per user, in minutes, in order: CTOL, rail, bus, auto, STOL.
TRAINS	Annual number of trains.
YEAR2	Year of energy data, four digits, used to check that demand and energy data match.
ACCESS(7,4,4,6)	Access modal split and energy variables: (city, intercity mode, access mode, energy parameter) see program listing, lines 87-107 for details.
EILINK(7,7,6)	Intercity energy factors: (Intercity link, intercity mode, energy factor) see program listing, lines 117-137 for details.
DIST(7,8)	Intercity distances in miles (link, mode). Links: 1, Montreal-Quebec City; 2, Montreal-Ottawa/Hull; 3, Montreal-Toronto; 4, Toronto-Ottawa/Hull; 5, Toronto-Windsor; 6, Toronto-London; 7, Toronto-Sudbury. modes: 1, CTOL; 2, rail; 3, rural bus; 4, urban bus; 5, rural auto; 6, urban auto; 7, STOL; 8, great circle distance.
TRNNRG	Intercity rail infrastructure construction energy, Btu/train departure. If less than 1.0 not used in calculations.

```

54      CALL CALC
55      ICOUNT = 1
56 C
57 C      Now the demand that is outputted from
58 C      the model is made into a ratio with base
59 C      year demand so as to compare future years.
60 C
61 C      ie:  NEW TRAFFIC = BASE TRAFFIC * MODEL NEW TRAFFIC
62 C
63 C
64 C      -----
65 C      MODEL BASE TRAFFIC
66 C
67 C      This is also done with modal splits
68 C
69 C      RATIO = TRAFIK / TOTAL
70 C      DO 30 I=1,4
71 C      RATIO(I) = AMS(I) / PMODE(I)
72 C
73 C      The base year data may be printed
74 C
75 C      CHECK = 4
76 C      J=0
77 C      READ(1,40),ANSWER
78 C      IF(ANSWER.EQ.YES) CALL PRINT
79 C      FORMAT(A1)
80 C
81 C      A copy of base year load factors is made
82 C
83 C      DO 50 I=1,4
84 C      BSYRLF(I) = ALF(I)
85 C
86 C      Accuracy of the load factor computation
87 C
88 C      READ(1,10),ERROR
89 C
90 C      Maximum number of iterations
91 C
92 C      READ(1,10),ITER
93 C
94 C      Upper limits on load factors
95 C
96 C      READ(1,10),(UPPLIM(I), I=1,4)
97 C
98 C      Lower load factor limits
99 C
100 C      READ(1,10),(ALOLIM(I), I=1,4)
101 C
102 C      If the load factors are to be the same as
103 C      the base year then enter zero for both limits
104 C
105 C      DO 60 I=1,4
106 C      IF(UPPLIM(I).NE.0.) GOTO 60
107 C      UPPLIM(I) = BSYRLF(I)
108 C      ALOLIM(I) = BSYRLF(I)
109 C
110 C      CONTINUE

```

```

108 C
109 C   Call the setup routine
110 C
111 C   CALL SETUP
112 C
113 C   If this is the second or later future
114 C   year, set the frequencies to those output
115 C   for the immediately previous year.
116 C
117 C       IF (ICOUNT .LT. 2) GO TO 65
118 C       DO 62 I=1,4
119 62   FREQ(I) = FREQ(I)
120 C
121 C   Finding the frequencies that give
122 C   the desired load factors
123 C
124 65   DO 100 J=1,ITER
125 C
126 C   The demand model routine
127 C
128 C       CALL MODEL
129 C
130 C   New demand and modal splits from
131 C   base year ratios
132 C
133 C       TRAFIK = TOTAL * RATIO
134 C       DO 70 I=1,4
135 70   AMS(I) = PMODE(I) * RATIO(I)
136 C
137 C   Normalization, modal splits, load factors etc.
138 C
139 C       CALL CALC
140 C
141 C   Now a check routine to see that all load
142 C   factors are within the specified limits.
143 C
144 C       CHECK = 0
145 C
146 X   CALL PRINT
147 C       DO 90 I=1,4
148 C       UPTTEST = UPPLIM(I) + ERROR
149 C       ALTEST = ALOLIM(I) - ERROR
150 C       IF(ALF(I).GT.UPTTEST) FREQ(I) =
151 C       SIFIX(DEMAND(I) / (SEAT(I) * UPPLIM(I) / 100.))
152 C       IF(ALF(I).GT. UPTTEST) ALOLIM(I) = UPPLIM(I)
153 C       IF(ALF(I).LT.ALTEST) FREQ(I) =
154 C       SIFIX(DEMAND(I) / (SEAT(I) * ALOLIM(I) / 100.))
155 C       IF(ALF(I).LT.UPTTEST.AND.
156 C       SALF(I).GT.ALTEST) CHECK = CHECK + 1
157 80   IF(CHECK.EQ.4.) GOTO 110
158 90   CONTINUE
159 100  CONTINUE
160 C
161 C   The print table routine

```

```

162 C
163 110 CALL PRINT
164 C
165 C Compare another year to the base year?
166 C
167 READ(1,40),ANSWER
168 IF(ANSWER.EQ.YES) GOTO 200
169 C
170 C
171 WRITE(4,11)
172 11 FORMAT('1', ' ')
173 STOP 01
174 200 ICOUNT = 2
175 DO 210 I=1,4
176 210 FREQH(I) = FREQ(I)
177 GO TO 55
178 END
179 C
180 C
181 SUBROUTINE SETUP
182 C
183 COMMON /BLOC1/NAME(13)
184 COMMON /BLOC2/COST(4),TIME(4),FREQ(4)
185 COMMON /BLOC3/SEAT(4)
186 COMMON /BLOC4/POP1,POP2,Y1,Y2,PL
187 C
188 Name of the link
189 READ(1,10),(NAME(I),I=1,13)
190 C Cost for the trip
191 READ(1,20),(COST(I),I=1,4)
192 C Time for the trip
193 READ(1,20),(TIME(I),I=1,4)
194 C Frequency of departures
195 READ(1,20),(FREQ(I),I=1,4)
196 C Seats per departure
197 READ(1,20),(SEAT(I),I=1,4)
198 C Populations
199 READ(1,20),POP1,POP2
200 C Disposable income
201 READ(1,20),Y1,Y2
202 C Language pairing index
203 READ(1,20),PL
204 10 FORMAT(13A4)
205 20 FORMAT(8G)
206 RETURN
207 END
208 C
209 C
210 SUBROUTINE MODEL
211 C
212 COMMON /BLOC2/COST(4),TIME(4),FREQ(4)
213 COMMON /BLOC4/POP1,POP2,Y1,Y2,PL
214 COMMON /BLOC5/TOTAL,PMODE(4)
215 DIMENSION A(4),UMODE(4)

```

```

216 C
217 DATA A(1),A(2),A(3),A(4)/1.0,34.12,60.039,24.953/
218 C
219 SIGU=0.0
220 DO 10 I=1,4
221 UMODE(I)=A(I)*(COST(I)**(-.942)*TIME(I)**(-1.447)*
222 SFREQ(I)**.538)
223 10 SIGU=SIGU+UMODE(I)
224 YAVG=(POP1*Y1+POP2*Y2)/(POP1+POP2)
225 TOTAL=8.9923*(POP1*POP2)**.7674*YAVG**.5611
226 $*PL**.2311*SIGU**.5510
227 DO 20 I=1,4
228 20 PMODE(I)=UMODE(I)/SIGU
229 RETURN
230 END
231 C
232 C
233 SUBROUTINE CALC
234 C
235 COMMON /BLOC2/COST(4),TIME(4),FREQ(4)
236 COMMON /BLOC3/SEAT(4)
237 COMMON /BLOC6/AMS(4),DEMAND(4),ALF(4),TRAFIK,
238 $TLCOST(5),TLTIME(5),TLSEAT(5)
239 C
240 AMSSUM = 0.
241 TLCOST(5) = 0.
242 TLTIME(5) = 0.
243 TLSEAT(5) = 0.
244 C
245 C Sum up the modal splits
246 C
247 DO 10 I=1,4
248 10 AMSSUM = AMSSUM + AMS(I)
249 C
250 C Normalize
251 C
252 DO 20 I=1,4
253 20 AMS(I) = AMS(I) / AMSSUM * 100.
254 DO 30 I=1,4
255 DEMAND(I) = TRAFIK * AMS(I) / 100.
256 ALF(I) = DEMAND(I) / (FREQ(I)*SEAT(I))*100.
257 TLCOST(I) = DEMAND(I) * COST(I) / 1E5
258 TLTIME(I) = DEMAND(I) * TIME(I) / 6E4
259 TLSEAT(I) = SEAT(I) * FREQ(I)
260 TLCOST(5) = TLCOST(5) + TLCOST(I)
261 TLTIME(5) = TLTIME(5) + TLTIME(I)
262 30 TLSEAT(5) = TLSEAT(5) + TLSEAT(I)
263 RETURN
264 END
265 C
266 C
267 SUBROUTINE PRINT
268 C
269 COMMON /BLOC1/NAME(13)

```

```

270      COMMON /BLOC2/COST(4),TIME(4),FREQ(4)
271      COMMON /BLOC3/SEAT(4)
272      COMMON /BLOC4/POP1,POP2,Y1,Y2,PL
273      COMMON /BLOC6/AMS(4),DEMAND(4),ALF(4),TRAFIK,
274      STLCOST(5),TLTIME(5),TLSEAT(5)
275      COMMON /BLOC7/CHECK,J
276      COMMON /BLOC8/DATE,TIM,DAY
277      CHARACTER*10 DATE
278      CHARACTER*11 TIM
279      CHARACTER*3 LDAY
280 C
281      WRITE(4,10), (NAME(I), I=1,13), DATE(1:2), DATE(3:4),
282      & DATE(5:6), TIM(1:2), TIM(3:4), TIM(5:6)
283      WRITE(4,20), COST, TIME, FREQ, SEAT, DEMAND, TRAFIK, ALF,
284      SAMS, TLCOST, TLTIME, TLSEAT
285      WRITE(4,30), POP1, POP2, Y1, Y2, PL, J, CHECK
286 C
287 10   FORMAT('1', //, //, X, 13A4, 3X, 3(A, 1H ), X, 2(A, 1H:), A, /)
288 20   FORMAT(21X, 'Car', 9X, 'CTOL', 8X, 'Rail', 8X, 'Bus',
289      & 5X, 'Total', //, ' ', 73('-'), //,
290      & S' Cost', 9X, 4(5X, F6.0), 2/,
291      & S' Time', 9X, 4(7X, F6.0), 2/,
292      & S' Frequency', 4X, 4(3X, F6.0), 2/,
293      & S' Seats', 8X, 4(7X, F5.0), 2/,
294      & S' Demand', 7X, 5(3X, F0.0), 2/,
295      & S' Load factor', 2X, 4(5X, F5.1, ' '), 2/,
296      & S' Modal split', 2X, 4(2X, F0.5, ' '), 2/,
297      & S' Total cost', 3X, 5(X, F11.0), 2/,
298      & S' Total time', 3X, 5(X, F11.0), 2/,
299      & S' Total seats', 2X, 5(X, F11.0), 1/,
300      & S' ', 73('-'), //)
301 30   FORMAT (' Population', 10X, 2(X, F8.0), //,
302      & S' Disposable income', 3X, 2(2X, F7.1), //,
303      & S' Language Pairing Index', 2X, F6.4, //,
304      & S' Iterations = ', I2, '; ', I1, ' of 4 modes ',
305      & S' within required accuracy', //,
306      & S' Total cost and time in thousands of dollars',
307      & S' and thousands of hours')
308      RETURN
309      END

```

Appendix D

Energy Calculator Program

This program is written in FORTRAN77. Output is designed for pages 8 1/2 inches high and 15 inches wide, with 132 columns per line. See Figures B.1 to B.7 for sample output. STOL figures are not printed out on the summary page: Modal Energy Requirements, Efficiency and Productivity (Figure B.7) because of space limitations and the fact that STOL was not included in any of the scenarios studied. STOL output could easily be added on another page if necessary. The subroutine GETTIME provides date and time information and is a Carleton University computer system library routine. It can be eliminated from the program.

The program is designed to accept demand data on one input file and energy data on another.

The format of the demand inputs follows. Refer to variable definition list for details on inputs.

Data File Line No.	Variable	Comment
1.000	LINK	
2.000	YEAR	
3.000	SCENARIO	For output headings only
4.000	VOL	Intercity modal volumes
5.000	XLF	Intercity modal load factors
6.000	COST	User trip cost, by mode
7.000	TTIME	User trip time, by mode
8.000	TRAINS	Annual number of trains

The energy data file contains three major sections: access factors, intercity factors, intercity distances.

Data File Line No.	Variable	Comment
1.	YEAR2	This year must match demand file year
2. to 113.	ACCESS	Access data. These are input in order by city, by intercity mode, by access mode, and by parameter. Parameters are on one line per access mode. See Figure D.1. City order see lines 101-107 in listing.
114. to 162.	EILINK	Intercity energy data. Input several lines for each city pair. The order of the lines is: CTOL data, rail data, rural portion bus data, urban portion bus data, rural portion auto data, urban portion auto data, STOL data. Each line consists of, in order: Direct energy, Btu/seat mile; energy to provide fuel, % of direct; vehicle construction energy, Btu/seat mile; vehicle maintenance energy, Btu/seat mile; terminal operation & maintenance energy, Btu/passenger departure; and runway, guideway or highway operation & maintenance energy; Btu/seat served (except rail which is Btu/train mile). City pair order as shown in the program listing, lines 52-58.
163. to 169.	DIST	Intercity mode distances. Seven lines, one for each city pair. Each line contains mile distances in order: CTOL, rail, rural bus, urban bus, rural auto, urban auto, STOL, great circle distance. City pair order as in EILINK.
170.	TRNNG	Intercity rail infrastructure construction energy. Btu/train mile. If no construction is involved in the scenario, enter 0.00.

Figure D.1

Access Data Input Format

Access by private automobile	}	CTOL	}	CITY 1
Access by urban bus service				
Access by metro/subway				
Access by taxi/limosine				
	}	Rail	}	CITY 1
		Intercity Bus		
	}		}	CITY 2
		STOL		
etc.		etc.		etc.

Each line contains: access mode share of total access,%;
 direct fuel consumption,Btu/passenger access trip; energy
 to provide fuel,% of direct energy; vehicle construction
 energy, Btu/passenger access trip; vehicle operation and
 maintenance energy, Btu/passenger access trip; infrastructure
 operation and maintenance energy, Btu/passenger access trip.

Energy calculator program variables

<u>VARIABLE NAME</u> <u>(DIMENSION)</u>	<u>DEFINITION</u>
LINK	One digit from 1 to 7 to identify link being calculated, used to select link energy data.
YEAR	Year of demand data, four digits, used to check that year of energy data matches, also used in printouts.
SCENARIO	Name of scenario being calculated, 40 alphanumeric characters, used in printout.
VOL(5)	Modal volumes, in order, CTOL, rail, bus, auto, STOL.
XLF(5)	Modal load factors, %, in order: CTOL, rail, bus auto, STOL.
COST(5)	Modal trip cost, per user, in cents, in order: CTOL, rail, bus, auto, STOL.
TTIME(5)	Modal trip time, per user, in minutes, in order: CTOL, rail, bus, auto, STOL.
TRAINS	Annual number of trains.
YEAR2	Year of energy data, four digits, used to check that demand and energy data match.
ACCESS(7,4,4,6)	Access modal split and energy variables: (city, intercity mode, access mode, energy parameter) see program listing, lines 87-107 for details.
EILINK(7,7,6)	Intercity energy factors: (Intercity link, intercity mode, energy factor) see program listing, lines 117-137 for details.
DIST(7,8)	Intercity distances in miles (link, mode). Links: 1, Montreal-Quebec City; 2, Montreal-Ottawa/Hull, 3, Montreal-Toronto; 4, Toronto-Ottawa/Hull; 5, Toronto-Windsor; 6, Toronto-London; 7, Toronto-Sudbury. modes: 1, CTOL; 2, rail; 3, rural bus; 4, urban bus; 5, rural auto; 6, urban auto; 7, STOL; 8, great circle distance.
TRNNRG	Intercity rail infrastructure construction energy, Btu/train departure. If less than 1.0 not used in calculations.

IC(2)	Cities in intercity link: 1, Quebec City; 2, Montreal; 3, Ottawa/Hull; 4, Toronto; 5, Windsor; 6, London; 7, Sudbury.
TOTRAF	Total traffic, sum of VOL values.
TRPCST(6)	Total users' trip cost, in dollars, by mode: 1, CTOL; 2, rail; 3, bus; 4, auto; 5, STOL; 6, all modes.
TRPTIM(6)	Total users' trip time, in minutes, same order as TRPCST.
VACTOT(5,2)	Access volume, (intercity mode, city 1 or city 2) total of all travellers accessing each intercity terminal.
VACCESS(2,4,5)	Access mode volume (city 1 or 2, access mode, intercity mode).
ACENG(2,4,4,5)	Access energy (city 1 or 2, intercity mode, access mode, energy parameter).
PER(4,2)	Percent of total access done on all access modes (intercity mode, city 1 or 2).
V(7)	Intercity mode volume. Adds two "modes", see DIST mode list.
XXLF(7)	Intercity load factors. See DIST mode list.
H	Seat miles.
HLDR(7,5)	Line-haul energy (intercity mode, energy parameters).
HENG(5,5)	Line-haul energy (intercity mode, energy parameter) Total rural and urban bus, rural and urban auto.
AIENG(2,4,4)	Total indirect access energy (city 1 or 2, intercity mode, access mode).
AMENG(2,4,4)	Total access energy (city 1 or 2, intercity mode, access mode).
APENG(2,4,5)	Total access energy (city 1 or 2, intercity mode, energy parameter).
AITENG(2,4)	Total indirect access energy (city 1 or 2, intercity mode).
ATMENG(2,4)	Total access energy (city 1 or 2, intercity mode).
AHMENG(4,4)	Total access energy (intercity mode, access mode).

AHIENG(4)	Total indirect access energy (access mode).
AHTENG(4)	Total access energy (access mode).
AITOT	Total indirect access energy
ATOT	Total access energy
AHTMEN(4)	Total access energy (intercity mode).
AHIMEN(4)	Total indirect access energy (intercity mode).
HPTENG(5)	Total line haul energy (energy parameter).
HIENG(5)	Total line haul indirect energy (intercity mode).
HTENG(5)	Total line haul energy (intercity mode).
HITENG	Total indirect line haul energy.
HHENG	Total line haul energy.
CIENG(5,5)	Total energy (intercity mode, energy parameter).
CLIENG	Total indirect energy.
CLTENG	Total energy.
CPENG(5)	Total energy (energy parameter).
HSRFLG	Logical variable set to true if rail infrastructure construction is to be calculated.
CIPENG(5)	Total indirect energy (energy parameter).
CMENG(5)	Total energy (intercity mode).
PMA(6)	Actual passenger miles (intercity mode) "mode" 6 is total.
PME(6)	Effective passenger miles (intercity mode) "mode" 6 is total.
TBPMA(12)	Total Btu per actual passenger mile. Odd indices are line-haul portion, even indices are total for each mode. Modes are in order CTOL, rail, bus, auto, STOL, total.
TBPME(12)	Total Btu per effective passenger mile. Order as in TBPMA.

DBPMA(12) Direct Btu per actual passenger mile. Order
as in TBPMA. }

DBPME(12) Direct Btu per effective passenger mile. Order
as in TBPMA.

IBPMA(12) Indirect Btu per actual passenger mile. Order
as in TBPMA.

IBPME(12) Indirect Btu per effective passenger mile. Order
as in TBPMA.

```

1 C ENERGY CALCULATOR
2 C
3 C INPUT BEGUN AUGUST 13
4 C
5 C BY ALAN TAYLOR (C)1979
6 C
7 LOGICAL HSRFLG
8 INTEGER YEAR, YEAR2
9 DIMENSION ACCESS(7,4,4,6), ID(4)
10 DIMENSION TITLE1(5,2), TITLE2(5,5), TITLE3(7)
11 DIMENSION EILINK(7,7,6), DIST(7,8)
12 DIMENSION VOL(5), IC(2), ACENG(2,4,4,5)
13 DIMENSION HENG(5,5), AIENG(2,4,4), AMENG(2,4,4), APENG(2,4,5)
14 DIMENSION AITENG(2,4), ATMENG(2,4), AHMENG(4,4), AHTENG(4)
15 DIMENSION AHIENG(4), AHIMEN(4), AHTMEN(4), HPTENG(5), HIENG(5)
16 DIMENSION HTENG(5), CIENG(5,5), CPENG(5), CIPENG(5)
17 DIMENSION CMENG(5), HLDL(7,5), XLF(5), XXLF(7)
18 DIMENSION VACTOT(5,2), PER(5,2), VACCESS(2,4,5), V(7)
19 DIMENSION LINKID(6,7), MODEID(4), PARTIT(5,5)
20 DIMENSION NAME(3,7), SCENARIO(10), COST(5), TTIME(5)
21 DIMENSION PMA(6), PME(6), TBPMA(12), TBPME(12)
22 DIMENSION DBPMA(12), DBPME(12), TRPCST(6), TRPTIM(6)
23 DIMENSION IBPMA(12), IBPME(12)
24 CHARACTER*10 DATE
25 CHARACTER*11 TIME
26 CHARACTER*3 DAY
27 DATA AHIMEN/4*0.0/, AHTMEN/4*0.0/
28 DATA HENG/25*0.0/, HLDL/35*0.0/, ACENG/160*0.0/
29 DATA ID/1,2,3,5/
30 DATA LINKID /'MONTREAL-QUEBEC CITY'
31 S'MONTREAL-OTTAWA/HULL 'MONTREAL-TORONTO
32 S'TORONTO-OTTAWA/HULL
33 S'TORONTO-WINDSOR
34 S'TORONTO-LONDON
35 S'TORONTO-SUDBURY
36 DATA MODEID /'CTOLRAIL BUSSTOL'
37 DATA NAME/'QUEBEC CITY MONTREAL
38 S'OTTAWA/HULL TORONTO WINDSOR LONDON SUDBURY
39 DATA PARTIT/'FUEL CONSUMPTION
40 S,'ENERGY COST OF FUEL VEHICLE CONSTRUCTIONVEHICLE MAINTENANCE
41 S'INFRASTRUCTURE O&M
42 DATA TITLE1/'TRAFFIC (%)
43 S 'TRAFFIC (PASS./YR.)
44 DATA TITLE2/'FUEL CONSUMPTION
45 S'ENERGY COST OF FUEL
46 S'VEHICLE CONSTRUCTION
47 S'VEHICLE MAINTENANCE
48 S'INFRASTRUCTURE O & M
49 DATA TITLE3 /'ENERGY REQUIREMENTS (BTU)
50 C READ CITY PAIR (LINK)
51 OUTPUT(1), 'INPUT CITY PAIR (BY NUMBER)'
52 OUTPUT(1), 'MONTREAL-QUEBEC CITY = 1'
53 OUTPUT(1), 'MONTREAL-OTTAWA = 2'

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54      OUTPUT(1),'MONTREAL-TORONTO' = 3'
55      OUTPUT(1),'TORONTO -OTTAWA/HULL' = 4'
56      OUTPUT(1),'TORONTO -WINDSOR' = 5'
57      OUTPUT(1),'TORONTO -LONDON' = 6'
58      OUTPUT(1),'TORONTO -SUDBURY' = 7'
59      ICOUNT=0
60      CALL GETTIME(7,DATE,TIME,DAY)
61      READ(2,10) LINK
62      10 FORMAT(I1)
63      IF(LINK .GT. 7 .OR. LINK .LT. 1) GO TO 3000
64      OUTPUT(1),'YEAR?'
65      READ(2,20) YEAR
66      20 FORMAT(I4)
67      OUTPUT(1),'SCENARIO?'
68      READ(2,15) (SCENARIO(I),I=1,10)
69 15  FORMAT(10A4)
70      OUTPUT(1),'INPUT MODAL VOLUMES AND LOAD FACTORS (TWO LINES)'
71 130 OUTPUT(1),'IN ORDER: CTOL,RAIL,BUS,AUTO,STOL'
72      READ(2,50) (VOL(J),J=1,5)
73      READ(2,50) (XLF(J),J=1,5)
74      OUTPUT(1),'COSTS?'
75      READ(2,50) (COST(I),I=1,5)
76      OUTPUT(1),'TIMES?'
77      READ(2,50) (TIME(I),I=1,5)
78      OUTPUT(1),'ANNUAL NUMBER OF TRAINS ?'
79      READ(2,50) TRAINS
80      50 FORMAT(8G)
81 C
82 C READ ENERGY RATES, DISTANCE, AND YEAR (YEAR FOR A CHECK)
83 C
84 140 READ(3,20) YEAR2
85      IF(YEAR .NE. YEAR2) GO TO 3010
86 C
87 C READ ACCESS PARAMETERS, BY CITY(J), BY INTERCITY MODE(L)
88 C BY ACCESS MODE(M), AND BY PARAMETER(K)
89 C PARAMETER 1 IS THE ACCESS MODAL SPLIT FOR THAT
90 C ACCESS MODE.
91 C PARAMETER 2 IS THE DIRECT FUEL CONSUMPTION
92 C PARAMETER 3 IS THE ENERGY COST OF FUEL PRODUCTION AND SHIPPING.
93 C PARAMETER 4 IS THE VEHICLE CONSTRUCTION.
94 C PARAMETER 5 IS THE VEHICLE MAINTENANCE.
95 C PARAMETER 6 IS THE INFRASTRUCTURE O&M.
96 C
97 C ACCESS MODES ARE: 1=AUTO,2=BUS,3=METRO,4=TAXI/LIMO.
98 C
99 C INTERCITY MODES ARE: 1=CTOL,2=RAIL,3=BUS,4=STOL,AUTO HAS NO ACCESS
ENERGY
100 C
101 C CITIES ARE: QUEBEC CITY = 1
102 C MONTREAL = 2
103 C OTTAWA/HULL = 3
104 C TORONTO = 4
105 C WINDSOR = 5

```

```

106 C      LONDON      = 6
107 C      SUDBURY     = 7
108 C
109 C
110      DO 210 J=1,7
111      DO 210 L=1,4
112      DO 210 M=1,4
113      READ(3,60) (ACCESS(J,L,M,K),K=1,6)
114      60 FORMAT(6G)
115      210 CONTINUE
116 C
117 C READ INTERCITY RATES
118 C SIX RATES PER MODE(K)
119 C SEVEN MODES PER LINK(L)
120 C SEVEN LINKS(J)
121 C RATES ARE: 1=FUEL
122 C              2=ENERGY COST OF FUEL
123 C              3=VEHICLE CONSTRUCTION
124 C              4=VEHICLE MAINTENANCE
125 C              5=INFRASTRUCTURE O&M (TERMINALS)
126 C              6=INFRASTRUCTURE O&M (RUNWAYS, TRACKS, OR HIGHWAYS)
127 C
128 C FOR INTERCITY ENERGY CALCULATIONS ONLY,
129 C THE INTERCITY MODES ARE: 1=CTOL, 2=RAIL, 3=RURAL BUS
130 C 4=URBAN BUS, 5=RURAL AUTO, 6=URBAN AUTO, 7=STOL
131 C LINKS AS ON EARLY PRINTOUT.
132 C
133 C FOR HIGH SPEED RAIL, INFRASTRUCTURE CONSTRUCTION
134 C ENERGY IS READ AFTER THE LAST DISTANCES. IF THE ENERGY
135 C IS LESS THAN ONE (1), DON'T USE IT IN CALCULATIONS
136 C AND PRINTOUT.
137 C ENERGY IS INPUT IN TERMS OF BTU'S PER TRAIN.
138 C
139      DO 220 J=1,7
140      DO 220 L=1,7
141      READ(3,61) (EILINK(J,L,K),K=1,6)
142      61 FORMAT(6G)
143      220 CONTINUE
144 C
145 C READ INTERCITY DISTANCES
146 C SEVEN MODES PER LINK, PLUS GREAT CIRCLE DISTANCE
147 C SEVEN LINKS
148 C
149      DO 225 I=1,7
150      225 READ(3,50) (DIST(I,J),J=1,8)
151 C
152      READ(3,70) TRNNRG
153      70 FORMAT(1G)
154      HSRFLG = .TRUE.
155      IF TRNNRG .LT. 1.0) HSRFLG = .FALSE.
156 C
157 C CALCULATE ACCESS ENERGY ONE CITY AT A TIME.
158 C
159 C FIRST ESTABLISH THE CITIES CONCERNED FROM THE LINK

```



```

160 C
161 IF(LINK.EQ.1) IC(1)=1; IC(2)=2; GO TO 240
162 IF(LINK.EQ.2) IC(1)=2; IC(2)=3; GO TO 240
163 IF(LINK.EQ.3) IC(1)=2; IC(2)=4; GO TO 240
164 IF(LINK.EQ.4) IC(1)=4; IC(2)=3; GO TO 240
165 IF(LINK.EQ.5) IC(1)=4; IC(2)=5; GO TO 240
166 IF(LINK.EQ.6) IC(1)=4; IC(2)=6; GO TO 240
167 IC(1)=4
168 IC(2)=7
169 240 CONTINUE
170 C
171 C SO NOW WE KNOW THE CITIES
172 C
173 C CALCULATE THE INTERCITY MODAL VOLUMES
174 C
175 TOTRAF = 0.0
176 DO 250 M=1,5
177 TOTRAF= TOTRAF + VOL(M)
178 250 CONTINUE
179 C
180 C CALCULATE TRIP TIME AND TRIP COST
181 C
182 TRPCST(6) = 0.0
183 TRPTIM(6) = 0.0
184 DO 260 I=1,5
185 TRPCST(I) = COST(I) * VOL(I) / 100.
186 TRPCST(6) = TRPCST(6) + TRPCST(I)
187 TRPTIM(I) = TTIME(I) * VOL(I)
188 260 TRPTIM(6) = TRPTIM(6) + TRPTIM(I)
189 C
190 C CALCULATE ACCESS ENERGY
191 C
192 C M SELECTS ARRAY IC
193 C J SELECTS CITY
194 C K SELECTS ACCESS SPLIT AND ENERGY PARAMETERS
195 C L SELECTS INTERCITY MODE
196 C N SELECTS ACCESS MODE
197 C
198 DO 270 M=1,2
199 J=IC(M)
200 DO 270 L=1,4
201 VACTOT(L,M) = 0.0
202 PER(L,M) = 0.0
203 DO 270 N=1,4
204 VACCESS(M,N,L) = VOL(ID(L)) * ACCESS(J,L,N,1)/100.0
205 VACTOT(L,M) = VACTOT(L,M) + VACCESS(M,N,L)
206 ACENG(M,L,N,1)=VACCESS(M,N,L) * ACCESS(J,L,N,2)
207 ACENG(M,L,N,2)=ACENG(M,L,N,1) * ACCESS(J,L,N,3)/100.0
208 PER(L,M) = PER(L,M) + ACCESS(J,L,N,1)
209 DO 270 K=4,6
210 ACENG(M,L,N,K-1)=VACCESS(M,N,L) * ACCESS(J,L,N,K)
211 270 CONTINUE
212 C
213 C NOW CALCULATE INTERCITY ENERGY CONSUMPTION

```

```

214 C
215 V(1)=VOL(1)
216 V(2)=VOL(2)
217 V(3)=VOL(3)
218 V(4)=VOL(3)
219 V(5)=VOL(4)
220 V(6)=VOL(4)
221 V(7)=VOL(5)
222 XXL(1)=XLF(1)
223 XXL(2)=XLF(2)
224 XXL(3)=XLF(3)
225 XXL(4)=XLF(3)
226 XXL(5)=XLF(4)
227 XXL(6)=XLF(4)
228 XXL(7)=XLF(5)
229 C
230 C
231 DO 700 I=1,7
232 IF(XXL(I) .LT. 0.01) GO TO 700
233 H = V(I)*DIST(LINK,I)/XXL(I)
234 HLDR(I,1) = H*EILINK(LINK,I,1)
235 HLDR(I,2) = HLDR(I,1)*EILINK(LINK,I,2)/100.0
236 HLDR(I,3) = H*EILINK(LINK,I,3)
237 HLDR(I,4) = H*EILINK(LINK,I,4)
238 HLDR(I,5) = V(I)*EILINK(LINK,I,5)
239 700 CONTINUE
240 IF( XLF(5) .LT. 0.01 ) GO TO 712
241 710 HLDR(7,5) = HLDR(7,5) + VOL(5)*2.0/XLF(5)*EILINK(LINK,7,5)
242 DO 715 I=1,5
243 715 HENG(5,I)=HLDR(7,I)
244 IF( XLF(4) .LT. 0.01 ) GO TO 722
245 720 HLDR(6,5) = HLDR(6,5)+VOL(4)/XLF(4)*EILINK(LINK,6,6)
246 HLDR(5,5) = HLDR(5,5)+VOL(4)/XLF(4)*EILINK(LINK,5,6)
247 722 DO 725 I=1,5
248 725 HENG(4,I)=HLDR(5,I)+HLDR(6,I)
249 C
250 IF( XLF(3) .LT. 0.01 ) GO TO 730
251 HLDR(4,5)=HLDR(4,5)+VOL(3)/XLF(3)*EILINK(LINK,4,6)
252 HLDR(3,5)=HLDR(3,5)+VOL(3)/XLF(3)*EILINK(LINK,3,6)
253 730 HLDR(2,5)=HLDR(2,5)+TRAINS*DIST(LINK,2)*EILINK(LINK,2,6)
254 IF( XLF(1) .LT. 0.01 ) GO TO 732
255 HLDR(1,5)=HLDR(1,5)+VOL(1)*2.0/XLF(1)*EILINK(LINK,1,6)
256 IF(HSRFLG) HSRNRG = TRAINS * TRNNRG
257 732 DO 735 I=1,5
258 HENG(3,I)=HLDR(3,I)+HLDR(4,I)
259 HENG(2,I)=HLDR(2,I)
260 735 HENG(1,I)=HLDR(1,I)
261 C
262 C NOW MAKE SOME TOTALS
263 C
264 DO 290 M=1,2
265 DO 290 N=1,4
266 DO 290 J=1,4
267 AIENG(M,N,J)=0.0

```

```

258      DO 300 K=2,5
259      300 AIENG(M,N,J)=AIENG(M,N,J) + ACENG(M,N,J,K)
270      290 AMENG(M,N,J)=AIENG(M,N,J) + ACENG(M,N,J,1)
271 C
272      DO 310 M=1,2
273      DO 310 N=1,4
274      DO 310 K=1,5
275      APENG(M,N,K)=0.0
276      DO 310 J=1,4
277      310 APENG(M,N,K)=APENG(M,N,K) + ACENG(M,N,J,K)
278 C
279      DO 320 M=1,2
280      DO 320 N=1,4
281      AITENG(M,N)=0.0
282      ATMENG(M,N)=0.0
283      DO 320 J=1,4
284      AITENG(M,N)=AITENG(M,N) + AIENG(M,N,J)
285      320 ATMENG(M,N)=ATMENG(M,N) + AMENG(M,N,J)
286 C
287 C   END OF PAGE TYPE 1
288 C
289 C   NOW FOR PAGE TYPE 2
290 C
291      DO 330 J=1,4
292      DO 330 N=1,4
293      AHMENG(J,N)=0.0
294      330 AHMENG(J,N)=AMENG(1,J,N) + AMENG(2,J,N)
295 C
296      DO 340 J=1,4
297      AHIENG(J)=0.0
298      AHTENG(J)=0.0
299 C
300      DO 340 N=1,4
301      AHTENG(J)=AHTENG(J) + AHMENG(N,J)
302      DO 340 M=1,2
303      340 AHIENG(J)=AHIENG(J) + AIENG(M,N,J)
304 C
305      AITOT=0.0
306      ATOT =0.0
307 C
308      DO 350 J=1,4
309      AITOT=AITOT+AHIENG(J)
310      350 ATOT=ATOT + AHTENG(J)
311 C
312      DO 360 N=1,4
313      DO 360 J=1,4
314      AHTMEN(J)=AHTMEN(J) + AHMENG(J,N)
315      DO 360 M=1,2
316      360 AHIMEN(J)=AHIMEN(J) + AIENG(M,J,N)
317 C
318 C   END OF PAGE TYPE 2
319 C
320 C   DO   LINE HAUL TOTALS FOR PAGE TYPE 3
321 C

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322      DO 370 K=1,5
323      HPTENG(K)=0.0
324      HIENG(K)=0.0
325      370 HTENG(K)=0.0
326 C
327      DO 380 N=1,5
328      DO 380 K=2,5
329      380 HIENG(N)=HIENG(N) + HENG(N,K)
330 C
331      IF( HSRFLG ) HIENG(2) = HIENG(2) + HSRNRG
332 C
333      DO 390 N=1,5
334      390 HTENG(N)=HIENG(N) + HENG(N,1)
335 C
336      DO 400 K=1,5
337      DO 400 N=1,5
338      400 HPTENG(K)=HPTENG(K) + HENG(N,K)
339 C
340      HITENG=0.0
341      HHENG =0.0
342      DO 410 N=1,5
343      HITENG=HITENG + HIENG(N)
344      410 HHENG =HHENG + HTENG(N)
345 C
346 C END OF PAGE TYPE 3
347 C
348 C NOW DO TOTAL (LINK) ENERGY
349 C
350 C
351      DO 420 N=1,3
352      DO 420 K=1,5
353      420 CIENG(N,K)=HENG(N,K)+APENG(1,N,K)+APENG(2,N,K)
354      DO 425 K=1,5
355      CIENG(5,K) = HENG(5,K) + APENG(1,4,K) + APENG(2,4,K)
356      425 CIENG(4,K) = HENG(4,K)
357 C
358      CLIENG=0.0
359      CLTENG=0.0
360 C
361      DO 440 K=1,5
362      CPENG(K)=0.0
363      DO 430 N=1,5
364      430 CPENG(K)=CPENG(K) + CIENG(N,K)
365      440 CLTENG=CLTENG + CPENG(K)
366 C
367      IF( HSRFLG ) CLTENG = CLTENG + HSRNRG
368 C
369      CLIENG=CLTENG-CPENG(1)
370 C
371      DO 460 N=1,5
372      CIPENG(N)=0.0
373      CMENG(N) =0.0
374      DO 450 K=1,5
375      450 CMENG(N)=CMENG(N) + CIENG(N,K)

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```

376 460 CIPENG(N)=CMENG(N) - CIENG(N,1)
377 C
378 IF( HSRFLG ) CIPENG(2) = CIPENG(2) + HSRNRG
379 IF( HSRFLG ) CMENG(2) = CMENG(2) + HSRNRG
380 C
381 C DONE PAGE TYPE 4
382 C
383 C DO SOME CALCULATIONS FOR A SUMMARY PAGE
384 C
385 PME(6) = 0.0
386 PMA(1) = VOL(1) * DIST(LINK,1)
387 PMA(2) = VOL(2) * DIST(LINK,2)
388 PMA(3) = VOL(3) * ( DIST(LINK,3) + DIST(LINK,4) )
389 PMA(4) = VOL(4) * ( DIST(LINK,5) + DIST(LINK,6) )
390 PMA(5) = VOL(5) * DIST(LINK,7)
391 PMA(6) = PMA(4) + PMA(3) + PMA(2) + PMA(1) + PMA(5)
392 DO 500 I=1,5
393 PME(I) = VOL(I) * DIST(LINK,8)
394 500 PME(6) = PME(6) + PME(I)
395 II = 0
396 DO 510 I=1,5
397 K = II + 1
398 TBPMA(I+II) = HTENG(I) / PMA(I)
399 TBPMA(I+K) = CMENG(I) / PMA(I)
400 TBPME(I+II) = HTENG(I) / PME(I)
401 TBPME(I+K) = CMENG(I) / PME(I)
402
403 DBPMA(I+II) = HENG(I,1) / PMA(I)
404 DBPMA(I+K) = CIENG(I,1) / PMA(I)
405 DBPME(I+II) = HENG(I,1) / PME(I)
406 DBPME(I+K) = CIENG(I,1) / PME(I)
407 C
408 IBPMA(I+II) = HIENG(I) / PMA(I)
409 IBPMA(I+K) = CIPENG(I) / PMA(I)
410 IBPME(I+II) = HIENG(I) / PME(I)
411 IBPME(I+K) = CIPENG(I) / PME(I)
412 II = II + 1
413 510 CONTINUE
414 C
415 TBPMA(11) = HHENG / PMA(6)
416 TBPMA(12) = CLTENG / PMA(6)
417 TBPME(11) = HHENG / PME(6)
418 TBPME(12) = CLTENG / PME(6)
419 C
420 DBPMA(11) = HPTENG(1) / PMA(6)
421 DBPMA(12) = CPENG(1) / PMA(6)
422 DBPME(11) = HPTENG(1) / PME(6)
423 DBPME(12) = CPENG(1) / PME(6)
424 C
425 IBPMA(11) = HITENG / PMA(6)
426 IBPMA(12) = CLIENG / PMA(6)
427 IBPME(11) = HITENG / PME(6)
428 IBPME(12) = CLIENG / PME(6)
429 C

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430 C NOW DO THE PRINTOUT
431 C
432     DO 470 I = 1,4
433     CALL HEADNG(NAME(I,IC(1)),MODEID(I),YEAR
434     $,VOL(ID(I)),LINKID(1,LINK),SCENARIO,DATE,TIME)
435 C
436     WRITE(4,1410) (TITLE1(J,1),J=1,5),(ACCESS(IC(1),I,J,1),J=1,4),
437     $PER(I,1),(TITLE1(J,2),J=1,5),(VACCESS(1,J,I),J=1,4),VACTOT(I,1)
438 1410 FORMAT(' ',//,X,5A4,5(F8.1,5X)
439     $,//,X,5A4,4(F10.0,XXX),F10.0)
440     WRITE(4,1415) (TITLE3(L),L=1,7)
441 1415 FORMAT(' ',//,34X,7A4,/)
442     DO 1420 K=1,5
443 1420 WRITE(4,1425) (TITLE2(J,K),J=1,5),(ACENG(1,I,J,K),
444     $ J=1,4),APENG(1,I,K)
445 1425 FORMAT(' ',5A4,X,5(1PE10.4,XXX) )
446     WRITE(4,1490) (AIENG(1,I,K),K=1,4),AITENG(1,I),
447     $ (AMENG(1,I,K),K=1,4),ATMENG(1,I)
448 1490 FORMAT(' ',//,X,'INDIRECT ENERGY',6X,5(1PE10.4,3X),//
449     $ ,X,'TOTAL ENERGY',9X,5(1PE10.4,3X) )
450 C
451     WRITE(4,1500) (NAME(L,IC(2)),L=1,3)
452 1500 FORMAT(' ',//,X,3A4)
453 C
454     WRITE(4,1410) (TITLE1(J,1),J=1,5),(ACCESS(IC(2),I,J,1),J=1,4),
455     $PER(I,2),(TITLE1(J,2),J=1,5),(VACCESS(2,J,I),J=1,4),VACTOT(I,2)
456     WRITE(4,1415) (TITLE3(L),L=1,7)
457     DO 1422 K=1,5
458 1422 WRITE(4,1425) (TITLE2(J,K),J=1,5),(ACENG(2,I,J,K),
459     $ J=1,4),APENG(2,I,K)
460     WRITE(4,1490) (AIENG(2,I,K),K=1,4),AITENG(2,I)
461     $ , (AMENG(2,I,K),K=1,4),ATMENG(2,I)
462 470 CONTINUE
463 C
464 C THIS COMPLETES PRINTOUT OF PAGE TYPE 1
465 C NOW DO PAGE TYPE 2
466 C
467     WRITE(4,1510) YEAR,DATE(7:8),DATE(4:5),DATE(1:2),
468     $ TIME(1:8),(SCENARIO(I),I=1,10),(LINKID(M,LINK),M=1,6)
469 1510 FORMAT('1',25X,'TOTAL LINK ACCESS ENERGY ',I4,
470     $ 10X,3(A,1H ),X,A,/,
471     $ 38X,'(BTU)',//,27X,10A4,/,30X,6A4,/,
472     $ X,'ACCESS MODE: AUTO BUS METRO TAXI/LIMO'
473     $ ,6X,'TOTAL',8X,'TOTAL',//,64X,'INDIRECT',/,
474     $ ' INTERCITY',//, ' MODE',/)
475     DO 480 I=1,4
476     WRITE(4,1520) MODEID(I),(AHMENG(I,J),J=1,4),
477     $ AHMEN(I),AHTMEN(I)
478 1520 FORMAT(XX,A4,4X,6(1PE10.4,XXX) )
479 480 CONTINUE
480     WRITE(4,1530) (AHIENG(J,I),J=1,4),AITOT
481 1530 FORMAT(/,' TOTAL',//,' INDIRECT',X,5(1PE10.4,XXX))
482     WRITE(4,1540) (AHTENG(J),J=1,4),ATOT
483 1540 FORMAT(/,' TOTAL',//,' ENERGY',3X,4(1PE10.4,XXX),13X,F10.4)

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484 C
485 C END OF PAGE TYPE 2
486 C NOW DO PAGE TYPE 3
487 C
488     WRITE(4,1550) YEAR,DATE(7:8),DATE(4:5),DATE(1:2),
489     & TIME(1:8),(SCENARIO(I),I=1,10),
490     & (LINKID(M,LINK),M=1,6),(XLF(I),J=1,5)
491 1550 FORMAT('1',40X,'LINE-HAUL ENERGY ',14,21X,3(A,1H ),
492     & X,A,/,50X,'(BTU)',
493     & //,42X,10A4,
494     & //,43X,6A4,/,
495     & 30X,'CTOL',9X,'RAIL',9X,' BUS',9X,'AUTO',
496     & 9X,'STOL',8X,'TOTAL',/,
497     & 3X,'LOAD FACTOR',15X,5(F5.3,8X))
498     WRITE(4,1555) VOL,TOTRAF
499 1555 FORMAT(3X,'ANNUAL PASSENGERS ',4X,6(F10.0,XXX),/)
500     DO 490 J=1,5
501     WRITE(4,1560) (PARTIT(M,J),M=1,5),(HENG(N,J),N=1,5)
502     & ,HPTENG(J)
503 1560 FORMAT(3X,5A4,3X,6(1PE10.4,XXX) )
504 490 CONTINUE
505     IF( HSRFLG ) WRITE(4,1565) HSRNRG,HSRNRG
506 1565 FORMAT(' INFRASTRUCTURE CONST.',15X,1PE10.4,42X,
507     & 1PE10.4)
508     WRITE(4,1570) (HIENG(J),J=1,5),HITENG
509 1570 FORMAT(' ',/,/,3X,'TOTAL',/,3X,'INDIRECT',15X,6(1PE10.4,XXX),/)
510     WRITE(4,1580) (HTENG(J),J=1,5),HHENG
511 1580 FORMAT(3X,'TOTAL',/,3X,'ENERGY',17X,6(1PE10.4,XXX) )
512 C
513 C END OF PAGE TYPE 3
514 C NOW DO PAGE TYPE 4
515 C
516     WRITE(4,1590) YEAR,DATE(7:8),DATE(4:5),DATE(1:2),
517     & TIME(1:8),(SCENARIO(I),I=1,10),(LINKID(M,LINK),M=1,6)
518 1590 FORMAT('1',42X,'TOTAL ENERGY ',14,
519     & 22X,3(A,1H ),X,A,/,50X,'(BTU)',
520     & //,44X,10A4,
521     & //,45X,6A4,/,
522     & 30X,'CTOL',9X,'RAIL',9X,' BUS',9X,'AUTO',
523     & 9X,'STOL',8X,'TOTAL',/,
524     & WRITE(4,1555) VOL,TOTRAF
525     DO 1605 J=1,5
526     WRITE(4,1600) (PARTIT(N,J),N=1,5),(CIENG(I,J),I=1,
527     & 55),CPENG(J)
528 1600 FORMAT(3X,5A4,XXX,6(1PE10.4,XXX) )
529 1605 CONTINUE
530     IF( HSMFLG ) WRITE(4,1565) HSRNRG,HSRNRG
531     WRITE(4,1610) (CPENG(J),J=1,5),CLIENG
532 1610 FORMAT(///,XXX,'TOTAL',/,XXX,'INDIRECT ',14X,6(1PE10.4
533     & ,XXX),/)
534     WRITE(4,1620) (CMENG(J),J=1,5),CLTENG
535 1620 FORMAT(XXX,'TOTAL',/,XXX,'ENERGY',17X,6(1PE10.4,XXX) )
536 C
537 C NOW PRINT OUT SUMMARY PAGE

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538 C
539 WRITE(4,2000) (LINKID(I,LINK),I=1,6),YEAR,(SCENARIO(I)
540 & ,I=1,10),DATE(7:8),DATE(4:5),DATE(1:2),TIME(1:8)
541 2000 FORMAT('1',22X,6A4,XX,I4,XX,10A4,20X,3(A,1H ),X,A,/)
542 WRITE(4,2002)
543 2002 FORMAT(31X,'MODAL ENERGY REQUIREMENTS, EFFICIENCY',
544 & ', AND PHODUCTIVITY',/)
545 WRITE(4,2004)
546 2004 FORMAT(33X,'CTOL',21X,'RAIL',21X,' BUS',15X,
547 & 'AUTO',15X,'TOTAL',/)
548 WRITE(4,2006)
549 2006 FORMAT(24X,3('LINE-HAUL TOTAL',6X),
550 & 'LINE-HAUL',4X,'LINE-HAUL TOTAL',/)
551 WRITE(4,2010) (PMA(I),I=1,4),PMA(6),(PME(I),I=1,4),
552 & PME(6)
553 2010 FORMAT(' PASSENGER MILES',14X,1PE10.4,2(15X,1PE10.4)
554 & ,8X,1PE10.4,10X,1PE10.4,/, '(ACTUAL)',/,
555 & ' PASSENGER MILES',14X,1PE10.4,2(15X,1PE10.4)
556 & ,8X,1PE10.4,10X,1PE10.4,/,
557 & '(EFFECTIVE)',/)
558 WRITE(4,2020) (HTENG(I),CMENG(I),I=1,3),CMENG(4),
559 & HHENG,CLTENG
560 WRITE(4,2300)
561 WRITE(4,2030) (TBPMA(I),I=1,7),(TBPMA(I),I=11,12)
562 WRITE(4,2040) (TBPME(I),I=1,7),(TBPME(I),I=11,12)
563 WRITE(4,2050) (HENG(I,1),CIENG(I,1),I=1,3),CIENG(4,1),
564 & HPTENG(1),CPENG(1)
565 WRITE(4,2300)
566 WRITE(4,2030) (DBPMA(I),I=1,7),(DBPMA(I),I=11,12)
567 WRITE(4,2040) (DBPME(I),I=1,7),(DBPME(I),I=11,12)
568 WRITE(4,2060) (HIENG(I),CIPENG(I),I=1,3),CIPENG(4)
569 & ,HITENG,CLIENG
570 WRITE(4,2300)
571 WRITE(4,2030) (IBPMA(I),I=1,7),(IBPMA(I),I=11,12)
572 WRITE(4,2040) (IBPME(I),I=1,7),(IBPME(I),I=11,12)
573 WRITE(4,2070) (TRPCST(I),I=1,4),TRPCST(6)
574 WRITE(4,2300)
575 WRITE(4,2080) (TRPTIM(I),I=1,4),TRPTIM(6)
576 C
577 2020 FORMAT(' TOTAL ENERGY,BTU ',3(1PE10.4,XX,1PE10.4
578 & ,3X),1PE10.4,3X,1PE10.4,XX,1PE10.4 )
579 2030 FORMAT(' BTU/PASSENGER MILE ',3(1PE10.4,XX,1PE10.4
580 & ,3X),1PE10.4,3X,1PE10.4,XX,1PE10.4 ,/,
581 & '(ACTUAL)' )
582 2040 FORMAT(' BTU/PASSENGER MILE ',3(1PE10.4,XX,1PE10.4
583 & ,3X),1PE10.4,3X,1PE10.4,XX,1PE10.4 ,/,
584 & '(EFFECTIVE)',/)
585 2050 FORMAT(' TOTAL DIRECT ENERGY ',3(1PE10.4,XX,1PE10.4
586 & ,3X),1PE10.4,3X,1PE10.4,XX,1PE10.4 )
587 2060 FORMAT(' TOTAL INDIRECT ENERGY ',3(1PE10.4,XX,1PE10.4
588 & ,3X),1PE10.4,3X,1PE10.4,XX,1PE10.4 )
589 2070 FORMAT(' TRIP COSTS ($)',3(15X,1PE10.4),8X,1PE10.4,
590 & 10X,1PE10.4,XX,1PE10.4,/)
591 2080 FORMAT(' TRIP TIME (MINUTES) ',7X,2(1PE10.4,15X)

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592      & ,1PE10.4,8X,1PE10.4,10X,1PE10.4,XX,1PE10.4,/,,'1')
593 2300  FORMAT(' ')
594 C
595      STOP 01
596 3000  OUTPUT(1),'INCORRECT LINK NUMBER ENTERED'
597      ICOUNT=ICOUNT+1
598      IF(ICOUNT.GT.5) GO TO 3002
599      OUTPUT(1),'RETRY'
600      GO TO 5
601 3002  OUTPUT(1),'TOO MANY RETRIES, STOPPING HERE'
602      STOP 02
603 3010  OUTPUT(1),'ENERGY DATA YEAR DOES NOT'
604      OUTPUT(1),'MATCH TRAVEL DATA YEAR'
605      OUTPUT(1),'EXECUTION TERMINATED'
606      STOP 03
607      END
608 C
609 C
610      SUBROUTINE HEADNG(NAME,MODE,YEAR,VOL,LINKID,SCENARIO
611      & ,DATE,TIME)
612      INTEGER YEAR
613      DIMENSION TITLE(7),TITLE2(20),NAME(3,1),LINKID(6,1)
614      DIMENSION SCENARIO(10)
615      CHARACTER*10 DATE
616      CHARACTER*11 TIME
617      DATA TITLE/'ACCESS ENERGY REQUIREMENTS '/
618      DATA TITLE2/'ACCESS MODE:'
619      S,' AUTO BUS MET'
620      S,'RO TAXI/LIMO TOTAL'
621      WRITE(4,10) (TITLE(I),I=1,7),YEAR,DATE(7:8),DATE(4:5),DATE(1:2)
622      & ,TIME(1:8)
623      10 FORMAT('1',20X,7A4,8X,14,3X,3(A,1H ),X,A,/)
624      WRITE(4,30) (SCENARIO(I),I=1,10)
625 30    FORMAT(' ',24X,10A4)
626      WRITE(4,15) (LINKID(I,1),I=1,6),MODE,VOL
627      15 FORMAT(25X,6A4,XXX,A4,/,30X,F8.0,' PASS. PER YEAR',/)
628      WRITE(4,20) (TITLE2(I),I=1,20),NAME
629      20 FORMAT(' ',20A4,/,X,3A4)
630      RETURN
631      END

```

Appendix E

Urban and Rural Highway Distances

The energy consumption of buses and automobiles is significantly different on rural and urban highways. In energy calculations this has been accounted for by breaking the intercity trip into an urban portion and a rural portion.

Bus urban distances were measured from the bus terminals to the defined edge of the city. The edges of the cities were:

Quebec City: Autoroute 20 at interchange with highway 73. Levis buses also had the same edge-of-city.

Montreal: Eastbound: Autoroute 20 at Autoroute 25.
Westbound: Autoroute 40 at Senneville Road.

Ottawa: Eastbound: Highway 417 at Highway 17.
Westbound: Highway 7 at Glencairn.

Toronto: Eastbound: Don Valley Parkway at Highway 401.
Westbound: Highway 401 at Highway 427.
Northbound: Highway 11A at Highway 401.

Windsor: Highway 401 at Howard Avenue.

London: Highway 401 and Wellington Road.

Sudbury: Highway 69 (Regent Street South) at Armstrong.

Distances were scaled off of various maps. The urban distances are the sum of the measured distances for each city. The rural distance is the difference between the total highway distance and the total urban distance.

For auto a different procedure was used. The rural distance was the same as for bus. For Ottawa/Hull and Montreal automobile origins were available by zones from the STQL demonstration data summary³⁶. Toronto automobile origin zones were from the Toronto Island Airport Study³⁷.

The bus edge-of-city points were considered the intercity automobile terminus.

Distances were scaled off of maps to obtain weighted average distances for these three cities. Traffic originating on the rural side of the auto terminus, for example travellers to Ottawa from Scarborough, were given negative distances to the terminus for averaging. Destinations were assumed to have the same characteristics as origins.

For other cities, origin data for automobile broken down in zones was not available. Auto accesses were assumed to be from the centroid of population to the auto intercity terminus. Urban distances from population centroids to auto terminus were scaled off of maps.

Appendix F

Language Pairing Index

The language index is a measure of the proportion of the populations of two cities who speak the same language. This is an important consideration in demand modelling in Europe and bilingual Canada.

Let each city 1, 2 have english speaking populations E_1 , E_2 , french speaking populations F_1 , F_2 , bilingual populations B_1 , B_2 , populations speaking neither french nor english N_1 , N_2 and total populations T_1 , T_2 .

$$T_1 = E_1 + F_1 + B_1 + N_1$$

The index is given by:

$$\text{index} = \frac{(E_1 + B_1)(E_2 + B_2) + (F_1 + B_1)(F_2 + B_2) - B_1 B_2}{(T_1 - N_1)(T_2 - N_2)}$$

The population speaking neither french nor english is omitted from this calculation because of its relatively small size and lack of detailed breakdown in the source⁴¹.

Language and population figures are given in Table F.1

Table F.1

1971 Language and Population Figures

City	Total	English Only	French Only	Both English & French	Neither English nor French
Quebec City	480,410	5,705	358,075	116,350	280
Montreal	2,743,235	508,210	1,635,630	1,017,360	54,130
Ottawa/Hull	602,555	322,270	78,780	196,750	4,760
Toronto	2,628,125	2,350,125	5,300	159,815	112,880
Windsor	258,655	218,780	1,280	33,495	5,100
London	286,270	270,695	205	12,630	2,740
Sudbury	155,460	94,175	8,140	51,350	1,800

Source: Reference 41.

Appendix G

Trip Cost Adjustments due to Energy Cost Changes

Scenarios A, C, A', C' examine the implications of energy costs increasing 3% over the inflation rate as forecast by Energy, Mines and Resources²⁹. This price increase will not affect all modes equally because energy costs are different proportions of the modes' total costs. Assuming fare levels are relatively constant except for the energy cost portions and assuming fare levels are related directly to costs, it is possible to increase the energy cost portion of each fare to simulate the impact of energy cost increases.

Data for calculating energy/operating cost ratios for the three public modes can be found in various Statistics Canada catalogues^{42,43,44}. The data show that the energy/operating cost ratios are: CTOL, 19.7%; rail, 6.23%; and bus, 7.5%; for 1977. The data did not explicitly include energy for building heat or for some maintenance vehicles, but these portions may be small.

The portion of automobile perceived cost due to energy is difficult to define. A BMC study used 75% of auto perceived cost as being due to energy costs. 75% was used in this thesis³⁹.

The access/egress portions of the trip costs are also affected by energy price increases. The data available for access modes would allow a calculation to be made on each access mode but the difference in

cost between this level of detail and cost calculated assuming all access is by auto is so small as to be not worthwhile. Therefore, for energy cost increases, all access is assumed to be by automobile.

The calculation is done by splitting the trip cost into access/egress and line-haul portions. The energy proportion of each mode is multiplied by the annual increase in energy costs and added back to the other-cost portion.

Example: CTOL 1986 Montreal-Ottawa/Hull, costs in cents

1976 Access/Egress = 543

1976 Line-Haul = 2000

1986 Access/Egress = $543 [(0.75) (1.03)^{10} + 0.25] = 683$

1986 Line-Haul = $2000 [(0.197) (1.03)^{10} + 0.803] = 2136$

1986 Total trip cost = 2819

The results of these calculations are used for scenarios A and C.

Scenario C' is the same as C except CTOL line-haul portion is increased by 20% after the energy cost adjustment.

Scenario A' includes the same cost increases as scenario A but also includes a reduction in energy consumption costs due to technological fuel economy improvements.

The procedure for doing calculations for scenario A' is as follows: the inflated energy cost is found as for scenario A. It is then multiplied by the ratio of the new energy consumption rate/old energy consumption rate to get the A' energy cost.

Example: Bus Montreal-Quebec City cost in cents

1976 energy cost = 57.75 (line-haul)

1976 other costs = 712.25 (line-haul)

1976 line-haul cost = 770.

1991 energy cost before economy = $57.75 \times (1.03)^{15} = 89.97$

1991 energy cost with economy = $89.97 \times 0.90 = 81.0$

1991 A' line-haul cost = $81 + 712.25 = 793$

A similar calculation is carried out for access/egress, again assuming it is all by automobile.

Results of calculations for scenarios A, C, C' are in Tables A4.1, A4.2, A4.3, & A4.5. Results for scenario A' are in Tables A4.6, A4.7, and A4.8.

END

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FIN