transit development, and others, particularly in human services (e.g., the Social Security Act), have presented difficulties for agencies. Federal policies may unintentionally threaten services that are already provided by the private sector, such as Colonial Taxi.

Colonial Taxi is a successful example of a situation in which government agencies are working with the taxi industry and the taxi owner is the patron in technology transfer. All of the case studies involved in coordinating social service agency transportation have been successful, but in all of these cases effort and education were required to overcome initial reluctance by the agencies.

No compelling evidence was found in any of the case studies of unique circumstances that would preclude technology transfer. Key factors in transfer are the previously identified prerequisites and barriers. It should be emphasized, however, that all of the programs studied are to a great extent the personal accomplishments of individuals; effective transfer of local paratransit technology is not yet at the "cookie-cutter" stage.

It can be concluded that the evolution of paratransit fits the typical characteristics of the technology transfer model. As a new transportation technology, paratransit has experienced innovative leadership (typically from persons outside of the traditional professional community), the implementation of new concepts, and a growth-decay curve of staff development and interest. In most locales, the public transportation community is just in the process of getting used to these innovations.

Finally, there is evidence in these case studies that the successful paratransit organizations are those that are broadly conceived and operated. The paratransit concept has been criticized by some for implying a broad focus in transportation that is not relevant in practice. However, at least two of these case studies—Colonial Taxi and CADA—have evolved into organizations that encompass virtually the entire spectrum of paratransit service planning.

ACKNOWLEDGMENT

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Estimating the Costs of a Subscription Van Service

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The development and results of a model that examines in detail the costs associated with supplying subscription van service in a small urban community are discussed. The service is assumed to consist of a number of vehicles that travel fixed routes for an extended period of time. Start-up costs, equipment replacement, system growth, and other variables are incorporated in the analysis. The effects of depreciation, taxes, purchasing and leasing of equipment, and other parameters are monitored. Possible savings to participating commuters under service cost-recovery criteria are also investigated. The procedure developed was implemented by a series of interactive computer routines coded in APL and simulated in a hypothetical demand situation for the Fredericton, New Brunswick, area, and a sensitivity analysis of the major variables and assumptions was performed. The analysis indicated that the model produced reasonable estimates of the results of introducing subscription van service in the Fredericton area. The development of the model is described, and a representative module is provided to show the level of detail undertaken in the analysis. Results of the simulation runs are presented, and variables in the sensitivity analysis that were found to have major impacts on the economic viability of subscription van service are discussed.

Many innovative transportation schemes have been suggested to alleviate existing urban commuting and parking problems. Most of these programs, however, tend to be long-term solutions for a very current problem. The technology required for some proposed solutions is not yet available. Other proposals have associated implementation costs that are prohibitive under current economic conditions. These problems of application are especially prominent in smaller urban areas such as those typical of the Atlantic Region of Canada and many areas of the United States.

Increasing the efficiency of existing transportation facilities is one way of alleviating many of the current transportation problems in these urban centers. Although this may be only an interim solution, such increases in efficiency can be realized in any urban center, regardless of size, and show almost immediate results.

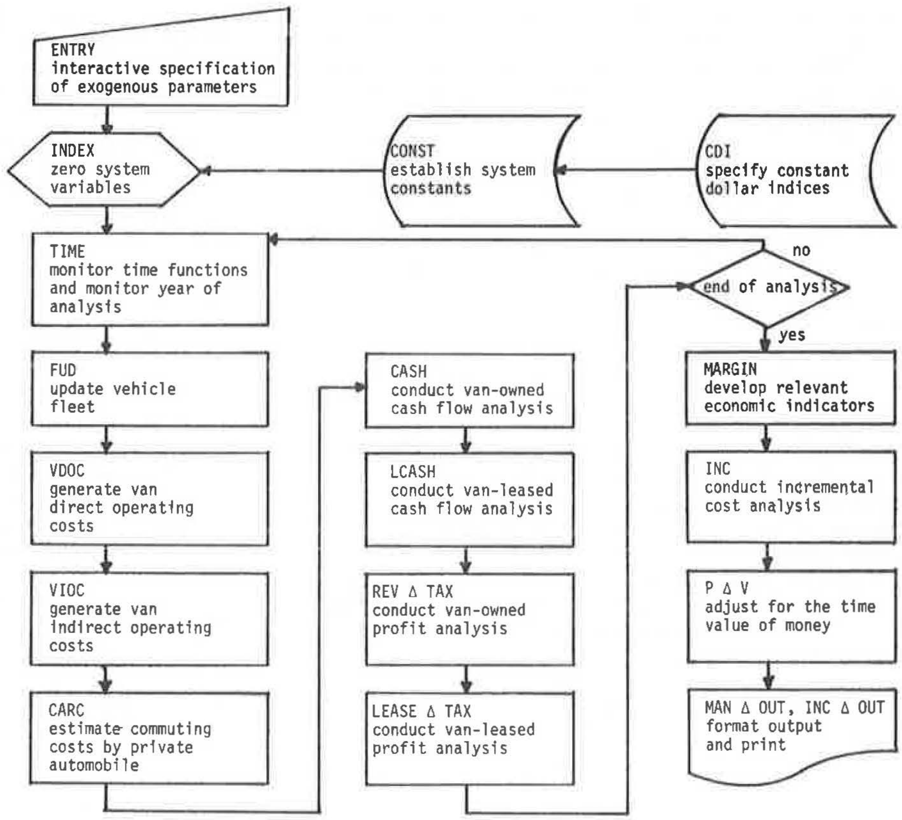


Figure 1. Methodology for economic analysis of subscription van service.

Thus, every effort should be made to implement any economically sound scheme that will increase the efficiency of transportation systems.

Pooling the daily work trip is one proven way of increasing the efficiency of transportation systems, and one of the more innovative applications of pooling in the journey to work is vanpooling. Several vanpooling programs have been established in North America in the past decade. Many have been very successful; each, however, has had its merits and demerits.

Before the implementation of a vanpooling program, the proposed service should be thoroughly assessed on an economic basis. In making such an assessment, the analyst is faced with two major questions: Should the service be implemented? If so, in what format and how extensive should the system be? To answer these questions, one must analyze the proposed service for various levels of implementation.

The research reported in this paper was an attempt to simplify this analysis for a subscription van service by developing a workable simulation package to assess the effect of various supply strategies on several economic parameters. The parameters investigated concern both the operation of the service on a managerial basis and incremental costs encountered by commuters who participate in the program. To test the model, a hypothetical demand situation for the Fredericton, New Brunswick, area was used and a sensitivity analysis was conducted on the major exogenous parameters.

DESCRIPTION OF THE MODEL

A flow diagram of the simulation package developed is shown in Figure 1. The model provides for a parallel analysis of both van-owned and van-leased operation. No provision was made in the model for the analysis of a combination of the two even though a fleet composed of both owned and leased vehicles might well be an appropriate strategy.

Each type of operation is considered to be a corporation, and the capital required is assumed to be borrowed for a length of time and at an interest rate that are designated at each particular application of the model. Direct and indirect operating costs, interest, revenue, leasing-related costs, and tax or subsidy computations are performed as required. Van-owned and van-leased cost figures are used to calculate net profits on an annual as well as a periodic basis, and return on investment is determined on an annual basis. In addition, incremental costs to commuters who use the service are estimated for services that are found to operate on a cost-recovery basis.

Economic comparison of van-owned and van-leased operations on an annual basis is clearly not valid because of the relatively uneven cash-flow situation of a van-owned operation and the constant cash-flow situation of a van-leased operation. Thus, provision was made in the model to analyze the subscription van service over an extended period of time. This required that all costs be set to constant (1975) dollars to allow for relative inflation rates for different cost items. It was also necessary to consider the time value of money and to incorporate this value into the analysis.

Data used in the model were extracted from various published sources. For situations in which no data were available, assumptions were made. The major assumptions concerning the operation of the service were as follows:

1. The system analyzed is a typical subscription van service (or vanpool operation) that uses conventional vehicles to transport commuters who travel to the same or immediately adjacent jobsites.
2. There is an adequate supply of vans.

3. No deadheading is associated with the commuting trips.
4. The residence of the average patron of the service is located seven-eighths the length of the van's journey from the jobsite.
5. All users of the service live on the normal route the van would follow to the place of work.
6. All capital assistance to the project is borrowed.
7. Costs for planning, design, and monitoring of the system are extraneous and are not included in the analysis.
8. All financial negotiations occur on an annual basis at the beginning of the year.
9. An 8 percent provincial sales tax is included in the leasing costs and purchase price of the vehicles.

The major assumptions concerning incremental costs encountered by commuters who use the service were as follows:

1. The introduction of a subscription van service will not produce any savings in the fixed costs of owning a vehicle for individual participating commuters.
2. The cost of time to the commuter is subjective and irrelevant to an incremental monetary analysis.
3. Ridership for the service is drawn equally from all sectors of the community population.
4. The personal vehicles of individuals who use the service are not used to a greater extent during working hours than they were before the switch to the vanpool service.

Several other minor assumptions were also incorporated into the analysis.

MODEL DEVELOPMENT

The model was implemented by a series of subroutines, or modules, coded in APL. Each element in Figure 1 represents one of these modules. All cost items were estimated in a disaggregate manner. A detailed description of the VDOC module will serve to illustrate the level of detail at which the analysis was undertaken.

The following computations were necessary to develop direct operating costs within the VDOC module. Assuming that the work year consists of 250 days and 5 percent additional van usage is encountered from miscellaneous travel, the average annual distance traveled by each van, in kilometers (KPY), is

$$KPY_y = 500 \times DIST \times 1.05 \times STUPF_y \quad (1)$$

where DIST is the average one-way trip distance for all vans (km) and STUPF is a start-up delay factor to allow for delays in pool formation during initial installation of the service.

DIST is an exogenous variable that is specified on each application of the model. STUPF, which is specified within the TIME module, was developed from documentation of the delays experienced during implementation of a subscription service (1).

Having determined van utilization, one estimates annual costs for the following items (in dollars per van). For fuel,

$$GASV = KPY_y \times PPL \times CDI_{z;6}/CONSV \quad (2)$$

where

PPL = cost of fuel (\$/L),
$CDI_{z;6}$ = constant dollar index for oil products for year z, and
CONSV = average expected fuel consumption (L/van).

Values for constant dollar indices were taken from a recent study on intercity highway passenger transportation (2) and adjusted where necessary to fit the current situation.

Routine oil changes are necessary for vehicle servicing. The cost of these is

$$OILV = KPY_y \times (NLPCV \times PPLO \times CDI_{z;6}) + (PPOF \times CDI_{z;5})/CI \quad (3)$$

where

NLPCV = oil required for an oil change (L/vehicle),
PPLO = cost of oil (\$/L),
PPOF = cost of an oil filter (\$), and
CI = distance between oil changes (km).

Assuming that the life of a tire is 32 000 km, annual tire costs per van are

$$TIREV = KPY_y \times 4 \times PPTV \times CDI_{z;2}/32\,000 \quad (4)$$

where PPTV is the cost of a van tire and $CDI_{z;z}$ is the constant dollar index for tires for year z.

Vehicle maintenance other than routine servicing was estimated as follows:

$$MAINV = KPY_y \times MCPVKV \times CDI_{z;5} \quad (5)$$

where MCPVKV is the average van nonroutine maintenance costs (\$/vehicle-km) (2) and $CDI_{z;5}$ is the constant dollar index for vehicle maintenance costs for year z.

Tolls and parking fees that would be encountered by the vehicles were determined by using

$$FEES = 250 \times (PARK + 2 \times TOLLS) \quad (6)$$

where PARK is the cost of parking (\$/vehicle/day) and TOLLS is the one-way tolls encountered by vans en route (\$/vehicle/day). PARK and TOLLS are both exogenous variables that are specified interactively. Therefore, from the above, total direct operating costs (in dollars per van per year) can be generated by using

$$DOCV_y = GASV + OILV + TIREV + MAINV + FEES \quad (7)$$

MODEL APPLICATION

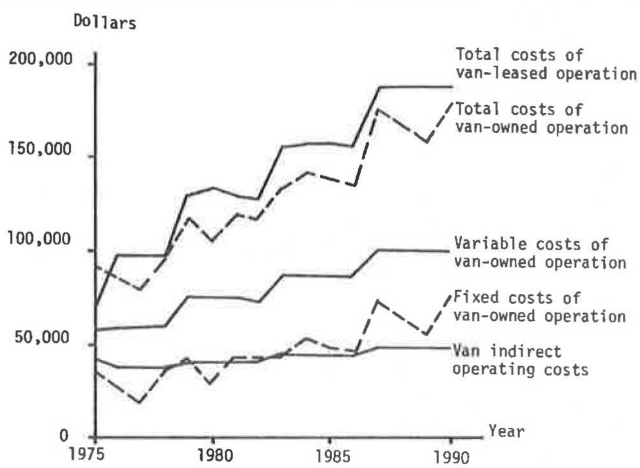
The model was used to assess the economic viability of implementing a subscription van service in the Fredericton area. Fredericton, a city of approximately 40 000, is the seat of the provincial government and the location of the University of New Brunswick. It is also a commercial center that has six shopping malls as well as a central business district. Several small industries are located in the city, but they play a minor role in the employment scheme. The variety of employment opportunities that the city provides makes it an employment center for several smaller "satellite" communities that are situated as far away as 70 km. Some people thus make very long daily commuting journeys. In fact, the situation is such that some individuals are currently operating private one-person, one-van services.

The demand for a subscription van service has been intuitively identified from a cursory examination of the work force and commuting patterns in the area. Since the demand figures in the simulation are only an engineering guess, the results of this analysis should not be interpreted as the necessary outcome of establishing a service in the area. Nevertheless, the model should give a good indication of what could happen if subscrip-

Table 1. Variables entered in simulation run.

Variable	Specification
Initial year of project	1975
Final year of project	1990
Number of vans to be operated each year	10, 10, 10, 10, 15, 15, 15, 15, 20, 20, 20, 20, 25, 25, 25, 25
Number of passengers per van per year	10
Replacement interval of vans in the van-owned operation	3 years
Proposed fare	\$0.07/km
Average one-way trip distance for all vans	40 km
Type of van to be operated	Conventional 12-passenger, six-cylinder vehicle with standard transmission
One-way tolls en route	Zero
Parking costs per vehicle per day	\$2.40/day
Interest rate on working and borrowed capital	0.115
Interest rate on invested capital	0.095
Length of debt payback period	Five years
Method of paying van driver	Indirect payment (free ride)
Average weighted speed limit en route	50 km/h
Commuter-traffic vehicle-occupancy rates for each year	1.65, 1.65, 1.66, 1.66, 1.67, 1.67, 1.68, 1.68, 1.69, 1.69, 1.70, 1.70, 1.71, 1.71, 1.72, 1.72

Figure 2. Operating costs (in constant 1975 dollars).



tion van service were introduced in the Fredericton area or a similar region.

The variables interactively entered to simulate the operation of a service in the Fredericton region are given in Table 1. The service was analyzed for the 1975-1990 period and was assumed to grow in a stepwise manner. Preliminary testing of the model indicated that interest costs dominate in loss situations. The fare to be charged for using the service was therefore specified at a level at which the service could operate at a modest profit.

On initial inspection, this fare appears to be high. An investigation of vanpooling in northern New Brunswick (3) found that the average fare charged was \$0.025/km. However, the vanpools in that area were generally providing a minimum of service. Many of the vans were carrying 15 people (besides the operator), and some were even being operated without heaters during the winter months. A fare of \$0.07/km may therefore not be as high as it initially appears.

The average one-way trip distance is only an estimate of what might be experienced. This variable would be a function of a detailed demand analysis, which was not undertaken. A conventional 12-passenger, six-cylinder van with standard transmission is specified as the type of vehicle used. Parking fees of \$2.40/day and payment of van drivers by way of a free ride are also noted.

Finally, the average weighted speed limit en route and vehicle occupancy rates (VOR) for commuter traffic for each year of the analysis are required to complete the exogenous, interactively specified parameters. Although the average commuter-oriented VOR in North America is approximately 1.4, an investigation of commuter traffic in the Fredericton area found the VOR to be 1.65. Whereas the VOR for commuter traffic in the Fredericton area is greater than normal, changes in factors that would tend to increase the VOR would probably have less overall effect in this area than in other areas. Nevertheless, current energy and economic situations indicate that some additional pooling in the journey to work is likely to occur in the next few years. Thus, a modest increase in the VOR over the analysis period was specified.

SIMULATION RESULTS

The detailed approach to costing illustrated by the description of VDOC above produced encouraging results. Many models developed in the past appear to merely restate the average unit costs on which they are based. To avoid this, all costs were treated in as detailed a manner as possible. As a result, the cost figures generated by the model appear to be dynamic in nature. Several cost fluctuations over the period analyzed are evident in the managerial analysis, particularly in the van-owned operation.

Figure 2 is a summary of the service costs generated by the model. As expected, the costs of the van-leased operation are quite stable. The only major changes are in the first year, because of start-up delays, and at four-year intervals, because of fleet increases. On the other hand, the costs of the van-owned operation are quite varied. Fluctuations in the variable costs of the van-owned service are similar to those for the van-leased operation. But changes in fixed costs are quite prominent. The variables that cause this include vehicle replacement, debt payments, interest costs on invested capital, and interest accrued on excess working capital. Indirect operating costs, which are assumed to be the same for both operations, amount to approximately 30 percent of all costs.

Except for the initial year, the estimated costs of a van-leased operation are consistently higher than the estimated costs of a van-owned operation. However,

Figure 3. Net profits (discounted to 1975 dollars by interest rate on borrowed capital).

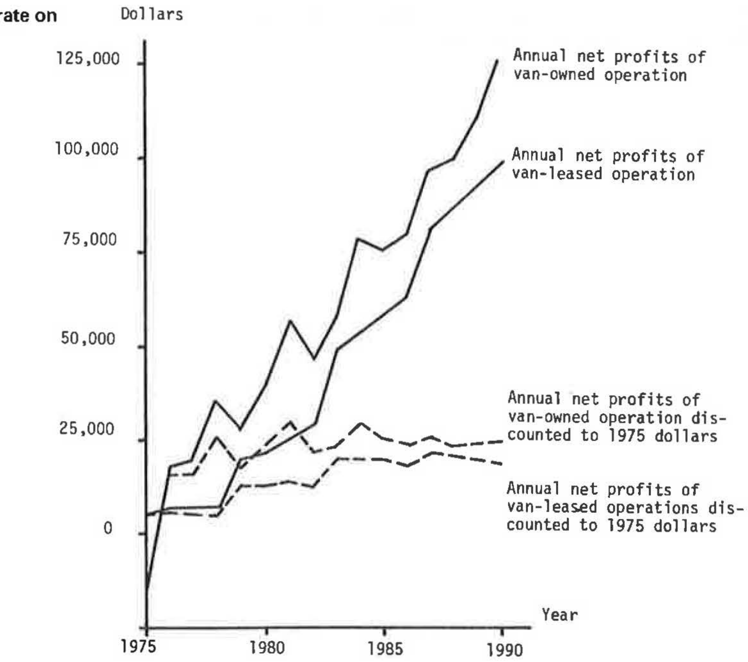
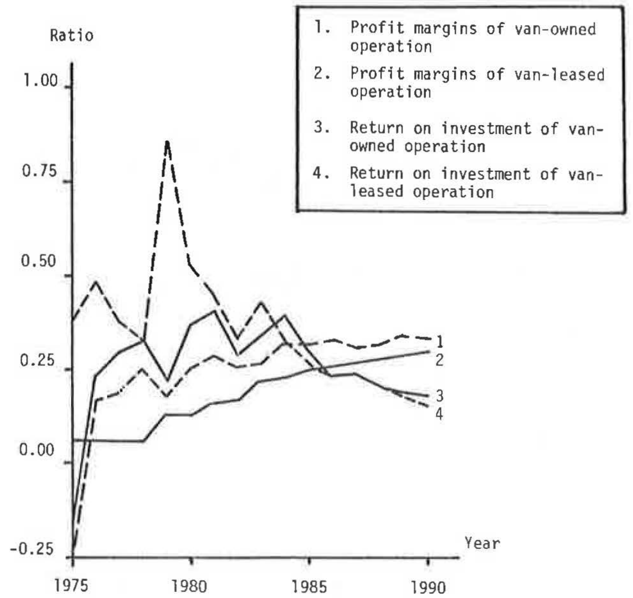


Figure 4. Investment criteria.



because of the nature of leasing agreements and the assumptions in the model concerning such agreements, these results could be misleading.

There are two basic types of leasing contracts: the net lease and the finance lease. In the net-lease contract, an extra mileage charge is levied on the lessee, and the responsibility of the used vehicle at the termination of the contract is on the lessor. On the other hand, a finance-lease agreement has no extra mileage charges, and, on termination of the agreement, provides definite advantages in situations in which the lessee may want to purchase the vehicle after leasing it for a period and prices of used vehicles are relatively high and stable. However, although finance-lease costs are probably lower, they are not easily predictable. Therefore, net-lease contractual costs were incorporated in the analysis. As a result, cost estimates in the van-leased analysis may be higher than those that would actually be encountered. A van-leased service may thus be more appropriate than Figure 2 would suggest, particularly in view of other factors such as cash flow and investment risk.

Net profits and net profits set to present value over the period analyzed are shown in Figure 3. As in the case of costs, van-leased net profits are quite stable and van-owned net profits fluctuate. However, as a result of the smoothing effect of setting figures to present worth, the net profits of both operations set to present worth are relatively consistent over the period.

Although net profits are greater in the van-owned operation, the annual return on investment realized in the van-leased operation is greater until the last few years of the analysis, as shown in Figure 4. This indicates the greater initial risk involved in a van-owned operation. In addition, the effects of additional costs encountered during service start-up are visible in both van-owned and van-leased return on investment. Profit margins, on the other hand, are consistently higher in the van-owned operation because of the higher net profits realized.

Costs to the commuter in the simulation run were found to be approximately 3.5 cents/km for commuting by automobile and were relatively constant over the analysis period. Thus, the incremental cost of using the service was found to be about 3.5 cents/km (in constant 1975 dollars). When one considers the assumptions noted earlier concerning incremental costs to the commuter, it appears that a major impetus for participating in a vanpool program would be the opportunity savings encountered from the disposition of a vehicle. In fact, one survey of vanpool participants found that 25 percent of the participants had either disposed of a vehicle, were planning on disposing of a vehicle, or had avoided buying a vehicle because of their participation in the vanpool program (4).

SENSITIVITY ANALYSIS

Two levels of sensitivity analysis were undertaken in this research. In a model of this nature, a sensitivity analysis of the exogenously specified variables can be useful.

Figure 5. Variations in net profits set to present value for van-owned operation (cumulative over study period).

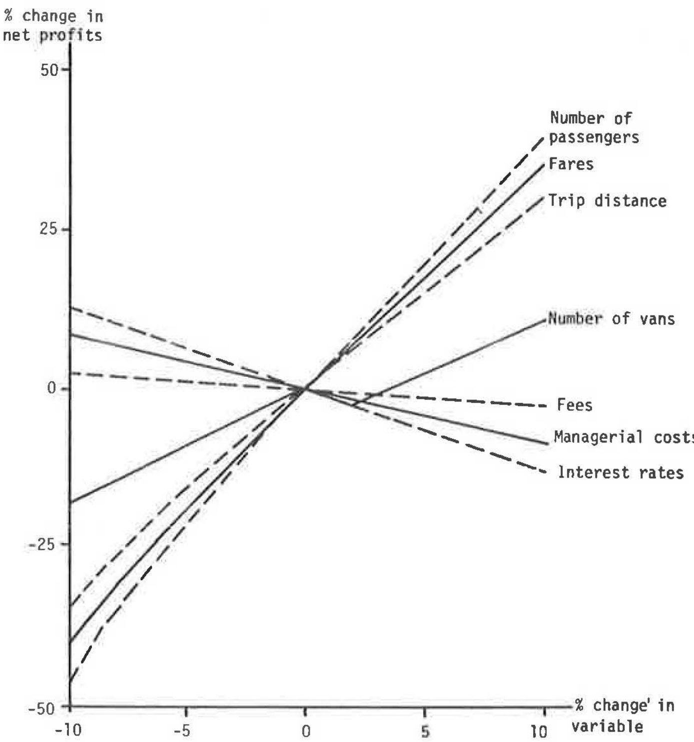
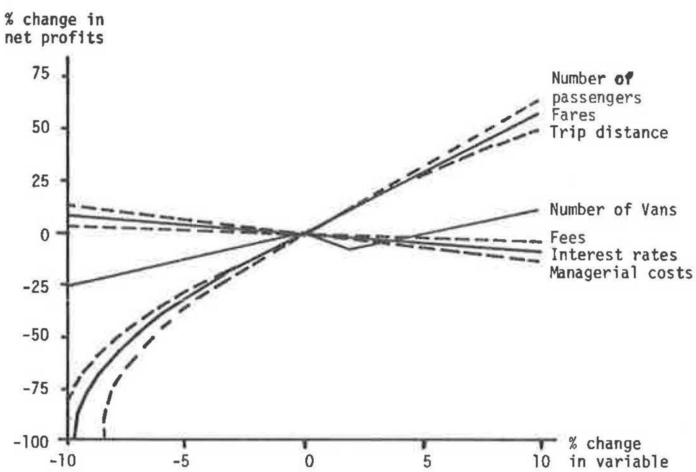


Figure 6. Variations in net profits set to present value for van-leased operation (cumulative over study period).



It provides an indication of how changes in the variables may influence the economic status of the operation and thus provides insight into what could happen when the service is implemented. In addition, since there is no way of actually testing the model, a sensitivity analysis of deviations in the basic assumptions is useful in delineating the possible scope of error. The hypothetical simulation run discussed above was used as a base run for the sensitivity analyses.

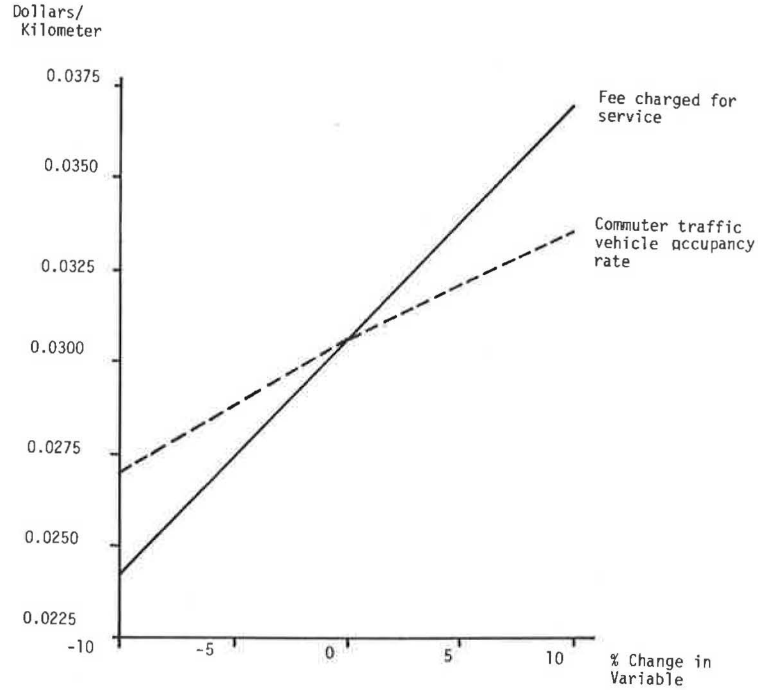
Effects of Alterations in the Exogenous Variables

Estimates of changes in net profits set to present worth for van-owned and van-leased operations on a ±10 percent variation in several of the major exogenous variables are shown in Figures 5 and 6. Of these parameters, the major factors that influence net profits are number of passengers, fares charged, and average distance traveled by the vans. A 10 percent variation in these factors was found to alter net profits set to present worth in the van-owned operation by 30-35 percent over the analysis period. Even greater differences were realized in the van-leased operation.

The effect of number of passengers is greater in this example than that of fares charged because the van operators are paid indirectly by way of a free ride. Direct payment of van drivers would make the effect of these variables consistent. The importance of interest rates in marginal and loss situations is clearly evident in Figure 6. Note that the slopes of the curves that represent number of passengers, fares, and trip distance increase drastically as net profits set to present worth approach a loss situation (-100 percent change in net profits).

Variations in number of vans produced a net profit curve similar in magnitude to that developed from altering the interest rate. However, the effects of these changes are diametric. In addition, the relative importance of interest rates and managerial costs differs in the two types of operations. A ±10 percent variation

Figure 7. Incremental costs to the commuter in 1990.



of the interest rate in the van-owned operation has more effect than a ±10 percent difference in managerial costs. But, since the van-lease operation exhibits a lower financial risk, variations in managerial costs are more influential than equivalent variations in interest rates. Fees were found to produce very little alteration in net profits set to present worth.

Because several of the exogenous variables were not amenable to alterations of ±10 percent, their sensitivity was assessed differently. In these analyses, changes in the vehicle power train, the loan pay-back period, and the method of driver payment were the only factors found to alter net profits considerably.

The vehicle power train was changed from a six-cylinder standard to an eight-cylinder automatic transmission. This reduced net profits set to present worth for the van-owned operation by 9.4 percent and for the van-leased operation by 13.8 percent. But, since differences in fuel consumption were not considered in this analysis, the actual variations in net profits realized could be greater.

The loan pay-back period was analyzed at annual intervals from 2 to 5 years. A reduction in the loan pay-back period was found to reduce net profits set to present worth in all cases; a net loss was encountered in the van-owned operation in the case of a loan pay-back period of 2 years. These results indicate that short-term loans should be avoided if possible. All loans undertaken were assumed to be paid over a fixed period of time. For this reason, loan prepayment—something that could be encountered in reality—was not considered in the model.

The method of paying van drivers was altered to direct payment. This reduced van-owned net profits set to present worth by 56.6 percent and caused a loss in the van-leased operation. The method of driver payment thus appears to be a critical factor in determining the economic feasibility of a service.

Estimates of changes in incremental cost to the commuter as a result of a ±10 percent variation in several of the major variables were developed. The factors found to significantly influence incremental cost to the commuter were the fee charged for the service and the commuter-traffic VOR. The effect of these variables is shown in Figure 7.

Effects of Alterations in Basic Assumptions

The only assumption that, when it was altered, markedly changed the results of the managerial analysis was the residential distribution of vanpool participants. Since the revenue generated by the service was the only cost item that would be altered by a different residential distribution and fares are specified as a function of distance, the impact of a ±10 percent variation in the residential distribution of vanpool participants was found to be identical to that of the same variations in the fare charged. Thus, the scope of possible model error in the managerial analysis can be delineated. But the possible scope of error on incremental costs to the commuter is not as clear.

In one operation, 25 percent of participating commuters were able to realize savings on an extra vehicle. When the effect of this savings was investigated, it was found to reduce incremental costs to the commuter by 87.6 percent (4). Another study (3) found that extra use of the family vehicle amounted on the average to 64 km/week, which would increase incremental costs to the commuter by 60.7 percent. Finally, at least one study (4) found that individuals who participated in a similar operation came from a commuting population that had an average VOR of 2.4, and that alteration was found to increase incremental costs to the commuter by 33.1 percent. Thus, each of these three phenomena could drastically alter simulation results. However, since it is highly unlikely that one of these factors would vary to a much greater extent than the others and since the total effect on incremental costs to the commuter of all three of the changes noted above is only an increase of 6.2 percent, the overall effect on the model of variations in these assumptions is probably minimal.

CONCLUSIONS

A simulation was run by using a hypothetical demand situation for the Fredericton area. The model appears to deal with the major variables in sufficient detail to produce dynamic results. In addition, a sensitivity analysis of the major variables and assumptions indicates that the model is producing reasonable estimates of what might be experienced if subscription van service were introduced. These results are encouraging.

Although development of the model itself was tedious, the actual simulation and sensitivity analyses included in this exercise were easily undertaken and could be done so in another application with a minimum of effort. The nature of APL is such that an individual who has little or no programming experience could use this simulation package after only a few hours at the terminal. Furthermore, the actual cost of applying the model to another locale would be minimal. The model could thus be a useful tool for assessing the viability of any proposed subscription van service or analyzing the variables that affect the costs of an existing service in an effort to increase efficiency.

The rather haphazard implementation of transportation services in the past has brought about the demise of many operations and contributed to developing skepticism about innovative transportation systems. In addition, the overall economic decline of transportation services in general dictates that planning decisions in the future must be more management oriented. Though specific applications should be analyzed thoroughly, this research may provide some general insight into the applicability of subscription van services in small urban communities. In fact, the technique used in this research could be applied to an analysis of the effect of implementing or expanding any transportation system.

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Economics of Vanpooling

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The concept of commuter vanpooling and the incentives that make it financially advantageous to the rider, the driver, and the company are examined. The primary incentive for riders is the money they can save on the commute to and from work. The farther the commute is, the greater are the savings. Convenience and camaraderie are also found to be important inducements for riders. For the driver, the incentives are a free commute to work, the possibility of getting rid of a second automobile, and personal use of the van on weekends. The incentives for 20 Texas firms that are currently operating approximately 310 vanpools are found to vary. Some companies initiated vanpooling to expand their labor market, some as a means of providing an increase in disposable income to employees, and some to save on parking costs. A detailed comparison of commuting and parking costs for automobile and vanpool is presented. Conditions in the state of Texas that have encouraged the use of vanpooling and future prospects for vanpooling in Texas are summarized.

Commuter vanpooling, as we know it today, was begun by the 3M Company in St. Paul, Minnesota, in 1973 (1). Since that time, vanpooling has generated a great deal of nationwide interest as an alternative mode of transporting people to and from work. Government agencies have focused on vanpooling as a means of reducing air pollution, saving energy, and easing traffic congestion. The 3M Company, however, was motivated by other needs. Specifically, Robert Owens of 3M was looking for a way to reduce parking demand so that the company would not have to build a very expensive parking garage.

In Texas, vanpooling got its start in early 1975 when the Continental Oil Company initiated a 10-van pilot program in Houston (2). By the end of 1977, there were some 14 programs in Texas and a total of 180 vans on the road (3). Estimates for the beginning of 1979 show about 310 vans in 20 programs across the state. A poll of employers who have initiated vanpooling reveals a number of significant reasons for starting programs, most of which are financial:

1. To provide employees with a "tax-free" fringe benefit that would increase disposable income in lieu of a raise,
2. To reduce the employer's share of parking costs, and
3. To expand the labor market in a region of low unemployment.

Conserving energy, reducing pollution, shifting the balance of payments, reducing traffic congestion, and other such lofty motivations were not among the reasons given for implementing vanpool programs.

The Texas Vanpool-Carpool Program, which is being conducted by the Governor's Office of Energy Resources and funded by the U.S. Department of Energy, seeks to accelerate the growth of vanpooling (and carpooling). The state's goal is to have 1500 vans on the road by the end of 1980. The basic strategy is to sell the state's largest employers on the vanpool concept and to provide