

Cost-Efficiency of Intercity Bus Technology Innovations

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Intercity bus transportation in Canada is in need of innovations to reduce costs and enhance passenger and cargo revenues. Higher-capacity buses, with improved passenger comfort and enlarged cargo space, could replace the existing standard coach in serving high traffic loads and thus eliminate the need for dispatching two or three buses simultaneously. Research is reported on the cost-efficiency of three new bus technologies vis-à-vis the standard coach, namely an articulated bus, a rigid body double-deck bus, and an articulated double-deck bus. Variations of bus design options in terms of costs and seating densities are also defined. Six routes in the Quebec-Windsor corridor are used for the assessment of bus technology options. Two analytical models were used for cost-efficiency analyses. The incremental supply and cost model compares relative cost-efficiencies for simulated passenger loading levels. The route supply and cost model estimates the supply of buses required to serve demand and also calculates unit costs for specific routes. Results reported here indicate the relative potential of high-capacity bus options for cost savings as well as operational factors related to their application.

Intercity bus transportation in Canada is in need of productivity improvements to offset the effects of cost escalation and changes in ridership. This low-cost and largely self-supporting mode has experienced a significant decline in ridership and profit in recent years. After almost constant ridership throughout most of the 1970s, the intercity bus mode experienced a net decline of more than 12 percent during the 1980–1984 period (1). Its market share has also been declining over the years. In recent years its profit has declined in actual as well as constant dollars (2).

The intercity bus industry in Canada is concerned about the declining profit and market share trend. The impacts of cost escalation and an unfavorable passenger market situation are obvious in the form of declining profit, given that about 68 percent of this industry's revenues are earned from scheduled passenger services (versus 10 percent from charter, 17 percent from parcel express, and 5 percent from other) (1982 figures, rounded) (1, 3). Clearly, this industry needs cost-effective means of improving service and curbing its escalating costs.

Among other innovations for increasing productivity and efficiency, vehicular technology innovations are expected to play a major part because these could improve ridership as well as the cost picture. On the passenger side, surveys show severe passenger dislike of the standard coach. More than 60 percent

of respondents complained of excess vibrations and lack of work space during transit. About 50 percent complained of excess jolts and rough rides, noise, and lack of ventilation (4, 5). Major difficulties also exist in controlling labor and other costs. Clearly, cost-effective means are required for favorable cost and service outputs.

Technology-based opportunities exist for improving the service and productivity of the intercity bus industry. In addition to improving the standard coach (e.g., a wider body with improved suspension and energy efficient power plant), there is a need in Canada to develop and operate large (high-capacity) buses on routes that normally require overload buses.

Sufficient evidence is available of the role for higher-capacity, more-comfortable buses as replacements for the existing standard coaches in serving peak loads. For example, the three largest intercity carriers in Canada operate as many as 200 buses and employ some 450 drivers to operate second or overload buses. On numerous routes, two or three buses are dispatched simultaneously to meet surges in demand. On such high-density travel routes, an estimated 30 percent of bus departures are overload buses. Such duplication can be eliminated by higher-capacity coaches (4).

In addition to serving high traffic loads per departure on well-traveled routes and eliminating the need for second or overload buses during peak times, high-capacity buses have the potential to provide improved comfort and enhanced space for their users. At appropriate usage levels, substantial labor and fuel efficiencies are achievable (6). Another important advantage of large buses would be their extra (enlarged) valuable cargo and baggage capacity (4).

Unlike that of the air transportation industry, deregulation of the bus industry in Canada is not expected to reduce the demand for high-capacity vehicles because the intercity bus service structure is likely to intensify on well-traveled corridor routes. Increased peaking of traffic coupled with market concentration is not likely to lessen the need for high-capacity use. Because high-capacity buses would replace overload or extra sections, which are dispatched simultaneously, their use would not affect user perception of frequency of service.

This paper is a report on an investigation of the cost-efficiency of those technologies of the intercity bus that look most promising and that should be the focus of further research, development, and implementation. Canada's highest density corridor, the Quebec-Windsor corridor, is used in analyses as a site for cost-efficiency research studies.

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BUS TECHNOLOGY INNOVATIONS: HIGH-CAPACITY BUS

In Canada there has been an interest in the development and use of high-capacity buses for intercity service on a number of routes that normally rely on extra (overload) buses to serve demand during peak periods. A demonstration of technology and user acceptance features has already been completed on a European-built articulated bus. Follow-up activity is under way to develop and test an articulated bus for intercity scheduled service and charter operations. The manufacturer of this vehicle (Prevost) already has technical cooperation and financial assistance from the relevant agencies of the federal government including the Department of Regional Industrial Expansion (DRIE), Transport Canada, and the government of Quebec (6). At present, the concept of a high-capacity double-deck coach is under study at Transport Canada (7).

Research on the cost-efficiency of the various design options in active service contexts has been regarded as essential before their final development and production. This paper covers highlights of a research study on the cost-efficiency of the following new technologies vis-à-vis the existing standard coach for service in the Quebec-Windsor corridor (8).

1. An articulated bus,
2. A double-deck bus, and
3. An articulated double-deck bus.

A summary of the most important characteristics of each of the bus technology concepts, including the existing standard coach, is given in Table 1. For each bus type, a range of seating capacity is defined. Because there are options in seat throw (i.e., distance between seats), seating capacity can be varied for intended space per passenger.

TABLE 1 COMPARISON OF BUS SPECIFICATIONS (8)

Design Class	Dimension (m)			Seating	Cost (000s) in 1982 Dollars	No. of Axles
	H	W	L			
Single deck	3.3	2.5	12	43–47	200	3
Articulated single deck	3.5	2.5	18	61–80	300–400	4
Articulated double deck	4.0	2.5	18	100	500	4
Double deck	4.0	2.5	12	61–80	350–400	3

The articulated single-deck and the articulated double-deck buses are 50 percent longer than the standard coach. The double-deck bus, on the other hand, has the same length as the standard single-deck coach. In all cases, the width of the bus is the same as that of the standard coach. In this research, because of the focus on significant capacity gain, the option of a wider single-deck standard coach was not analyzed.

The maneuverability and stability characteristics of new bus designs can be studied in detail only through actual road tests after the manufacture of a selected type or types of buses. However, theoretical and computer simulations suggest that no problems are likely to be encountered. Although the new design concepts are intended to be highly advanced in terms of

technology components, generally similar designs have been in use in Europe. Therefore, from a technical performance perspective, no problems are expected. Only small structural changes to terminals would be required to allow these buses to be maneuvered (4, 5).

ESTIMATION OF COSTS

Intercity bus transportation costs are classified here as equipment acquisition, driver, operation, maintenance, and administration costs. Table 2 gives the percentage of total bus transportation costs accounted for by each category, based on the cost experience of the Voyageur bus company (9). Selected major carrier costs and operations data are noted in Table 3 (10).

Examination of these data suggests that technical efforts are required to improve costs of equipment acquisition, operation,

TABLE 2 TYPICAL INTERCITY BUS CARRIER
COST COMPOSITION (8)

Cost Item	Percentage of Total Cost
Bus unit leasing	11.3
Driver	
Wages and benefits	41.4
Expenses	2.1
Subtotal	43.5
Bus operation	
Tires	2.1
Fuel	11.9
Insurance	1.5
Licensing	1.2
Miscellaneous	0.8
Subtotal	17.5
Bus maintenance	
Wages and benefits	10.2
Parts	5.4
Cleaning	1.3
Exterior repair	2.0
Other	1.4
Subtotal	20.3
Administration overhead	7.4

TABLE 3 SELECTED MAJOR INTERCITY BUS
CARRIER COSTS AND OPERATIONS DATA (10)

Item	Value
Capital cost (\$)	180,000–200,000
Driver cost (\$/km)	0.5–0.6
Interest (%)	14–16
Utilization (km/year)	160 000–240 000
Fuel (L/km)	0.36–0.43
Fuel (\$/L)	0.31–0.44
Maintenance cost (\$/km)	0.15–0.20
Fuel consumption (km/L)	2.31–2.74
Overhead cost (\$/km)	0.12–0.20

NOTE: Dollar amounts are in 1982 dollars.

and maintenance on a unit cost basis. Labor and fuel efficiencies are especially important, and it is contended that, through the use of high-capacity buses, labor and fuel productivity enhancements become cost-effective. The importance of labor productivity can be appreciated from data presented in Table 2. Driver cost amounts to 43.5 percent of total costs. Wages and benefits for bus maintenance account for another 10.2 percent of total costs.

Although intercity bus transportation is fuel efficient relative to other modes, further improvements are achievable for the new vehicles under investigation. Payoffs are important for the industry because fuel costs amount to about 12 percent of total intercity bus transportation costs (Table 2). Fuel costs within the operation and maintenance costs of bus transportation amount to from 15 to 20 percent (11, 12).

Cost estimates for high-capacity options have been developed on the basis of an engineering unit cost approach because there are no statistical cost data available for new bus designs (8–10) (Table 4). The capital cost of an articulated bus is estimated to be approximately twice that of a standard bus. The double-deck bus is estimated to cost the same amount as an articulated bus. The capital cost of these buses is estimated to range from \$300,000 to \$400,000 (1982 dollars). Only one cost for the articulated double-deck bus, \$500,000, is used in this research in order to keep trade-off analyses to a manageable level.

Advanced-technology bus design, through the use of micro-electronics, improved materials, and other design features, is expected to reduce operating costs (such as those of fuel consumption) and maintenance costs (11–13). Because fewer units of the high-capacity bus will be required to carry the same number of passengers as standard buses, it would be cost-effective to install state-of-the-art diagnostic equipment on each unit. This would result in lower maintenance cost per seat-kilometer than the standard bus. Likewise, on the fuel consumption side, although an increase of 10 percent was estimated for both articulated and double-deck buses and a 25 percent increase for the articulated double-deck bus, their larger seating capacity would enhance their fuel efficiency (9, 10).

Driver wages for the high-capacity bus options are assumed to remain the same as those for the standard bus (9). Therefore

the driver cost of \$0.55/km (1982 dollars) has been considered for all bus technologies. Also, according to the intercity bus operators, the overhead cost would remain the same for both high-capacity buses and the standard bus. Therefore the overhead cost of \$0.16/km (1982 dollars) has been used for all technologies. Table 4 gives the details of costs for all bus technologies that are considered in this research.

ROUTES SELECTED FOR BUS TECHNOLOGY ASSESSMENT

The Quebec-Windsor corridor, which is Canada's highest density travel corridor, is generally well served by intercity travel modes (14). Freeway-type road facilities link principal centers in the corridor (Figure 1). The automobile and bus modes offer almost congestion-free service. As previously noted, intercity bus carriers are, however, required to operate extra buses during peak times in order to meet passenger demand. Thus the number of these extra sections could be reduced along with the cost of service if a high-capacity bus were available. These routes, given in Table 5, are therefore appropriate locations for the initial use of high-capacity buses in scheduled service. Intercity distances and origin-destination traffic are given in Table 5. The actual traffic served would be higher because of through traffic that uses the links chosen for this study.

ANALYTICAL MODELS

In theory, an analysis of the economic feasibility of a transport system alternative, such as a new bus technology, should be supported by a complete supply-demand interaction analysis in order to estimate demand for service and level of utilization (i.e., load factors). As noted previously, in the present case, the proposed use of the high-capacity bus as a replacement for the conventional coach is not expected to alter the scheduled (time) frequency of service. That is, passengers would be offered similar frequency of service whether these services were based on standard intercity coach or high-capacity buses. Likewise, there is no change in the fare structure.

There is, however, the prospect of enhanced ridership due to improved comfort and amenities on-board obtainable from the advanced technology of the high-capacity bus designs. Because travel demand estimation models in their present state of

TABLE 4 COST DETAILS OF STANDARD BUS AND TEST BUSES

Data Item	Standard Bus	Articulated or Double-Deck Bus Option			Articulated Double-Deck Bus
		A	B	C	
Bus cost (\$)	180,000–200,000	300,000	350,000	400,000	500,000
Seating	45	61/70/80	61/70/80	61/70/80	100
Interest (%)	14–16	14–16	14–16	14–16	14–16
Utilization (km/yr) (000s)	160–240	160–240	160–240	160–240	160–240
Bus cost (\$/km)	0.17	0.24	0.28	0.32	0.40
Maintenance cost (\$/km)	0.18	0.28	0.32	0.37	0.46
Fuel (\$/km)	0.15	0.17	0.17	0.17	0.19
Total bus cost (\$/km)	0.50	0.69	0.77	0.86	1.05
Driver cost (\$/km)	0.55	0.55	0.55	0.55	0.55
Overhead cost (\$/km)	0.16	0.16	0.16	0.16	0.16
Total cost (\$/km)	1.21	1.40	1.48	1.57	1.76

NOTE: Dollar amounts are in 1982 dollars.

SOURCE: Based on Nookala (8) and Hickling Partners, Inc. (10).

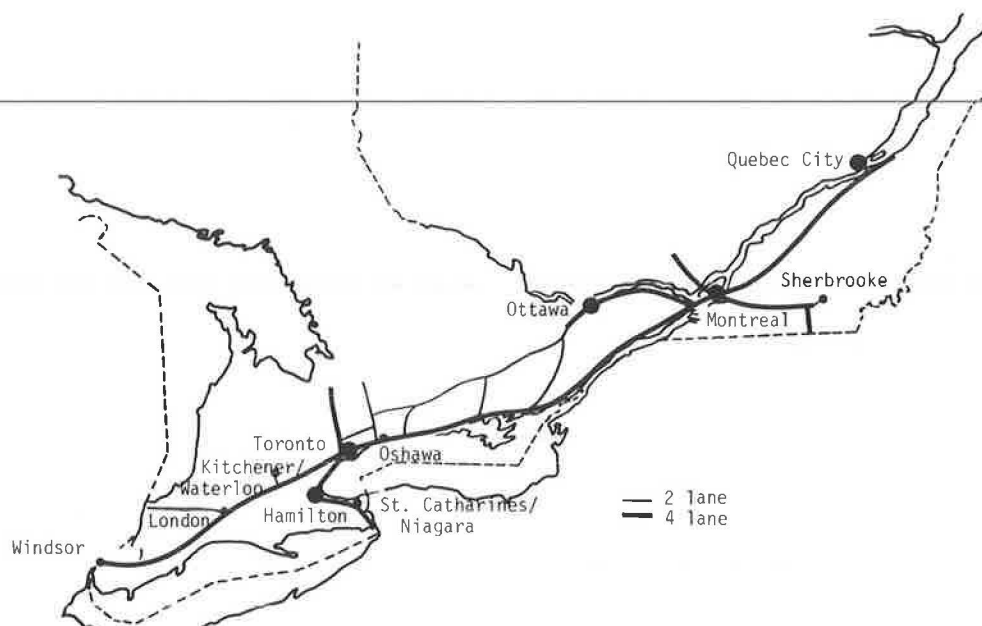


FIGURE 1 Principal intercity highway network, Quebec-Windsor corridor.

TABLE 5 STUDY ROUTES, DISTANCES, AND BUS PASSENGER TRAFFIC

City Pair	Distance (km)	Origin-Destination Passenger Traffic (thousands of one-way trips, 1976)
Montreal-Quebec City	253	702
Montreal-Toronto	540	207
Montreal-Ottawa	195	675
Toronto-Ottawa	395	283
Toronto-Windsor	380	45
Toronto-London	190	135

development cannot assess demand effects of such service attributes, it was considered appropriate to analyze the supply-side variable while holding demand level for the analysis year constant.

Under these conditions, it is necessary to investigate costs for incremental loading levels as well as to investigate costs under route-specific operating and demand conditions. Thus, for the estimation of the cost-efficiency of a new bus unit, two analytical methods were developed:

1. Incremental supply and cost model and
2. Route supply and cost model.

Incremental Supply and Cost Model

This model is intended to simulate passenger loading and calculate unit costs in terms of cost per passenger-kilometer for the bus technology options. This method can thus indicate if there are any levels of passenger demand at which a given high-capacity bus option would be cheaper to operate than the standard bus. Figure 2 is a flowchart of the model. The costs developed previously are used as input to the model.

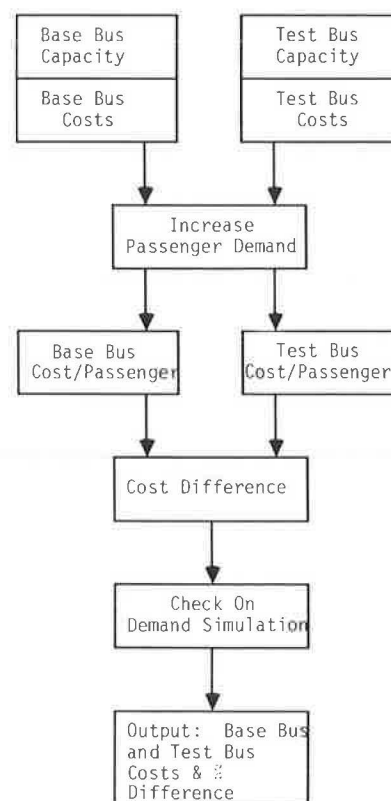


FIGURE 2 Incremental supply and cost model.

Passenger demand is varied from an initial value of 1 to a maximum of 270—a level of demand that is sufficiently high to cover a wide range of service conditions. From the total cost and passenger demand, unit costs are calculated for base and test buses. The next step is to find the difference in cost

between the base bus and the test bus and also the percentage difference in passenger-kilometer costs.

The current standard bus is assumed to carry 45 passengers (the average of the intercity operators' fleets). All high-capacity bus designs can then be compared with the baseline bus (45-seat standard coach) and results are plotted in terms of percentage difference in costs per passenger-kilometer.

The significance of the output of this model is that it enables the planner to establish whether there is any role for a proposed high-capacity bus option and also, in relative terms, which option is most attractive for various demand levels.

Route Supply and Cost Model

Figure 3 shows the logic diagram for this model. This model calculates the number of buses required to carry the number of passengers to be served on a specific route. Then, using the input cost information, it calculates the average total cost per passenger-kilometer, cost per bus-kilometer, and total cost per seat-kilometer. The data used are aggregates for the entire year.

Outputs of this model in the form of various unit costs make possible a comparison of the cost-efficiency of relevant bus design options for specific routes. In association with the results of the incremental supply and cost model, these outputs provide a complete picture of the role and cost-efficiencies of intercity bus technology options.

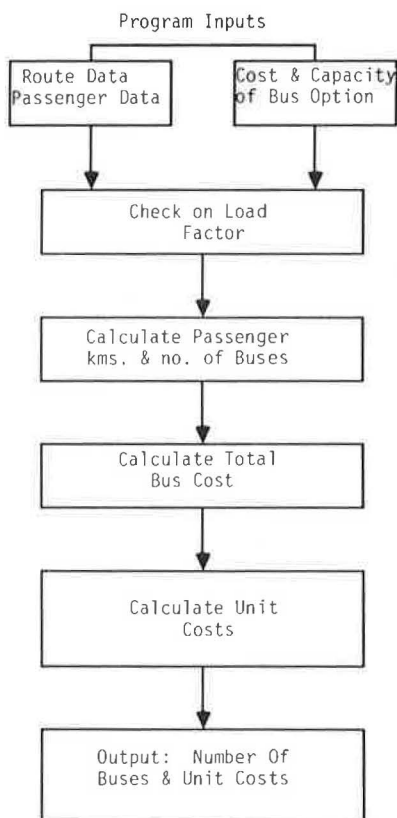


FIGURE 3 Route supply and cost model.

MODEL IMPLEMENTATION AND RESULTS

When the models were implemented, because of the non-availability of recent origin-destination and other passenger data, the bus travel demand for 1976 was used (8). However, according to Statistics Canada catalogs and other sources of data, growth in bus passenger demand on study routes from 1975 to 1985 was rather insignificant. Therefore cost calculations were made using 1976 passenger data (given in Table 5) with 1982 cost estimates.

Because the actual capital cost for the high-capacity buses was not known, a number of cost estimates were developed. As noted in Table 4, these are \$300,000, \$350,000, and \$400,000 for articulated and double-deck bus options. In the case of the articulated double-deck bus, only one estimate of capital cost, namely \$500,000, was used for comparative analysis. Comparisons between base bus and test bus were made with all cost calculations of high-capacity bus options.

Figures 4 and 5 show selected results achieved from the incremental supply and cost model applications. As shown in Figure 4, for the double-deck or articulated bus, although the larger size of the vehicle increases the cost by 17 percent, because of the need for a second conventional bus to serve the

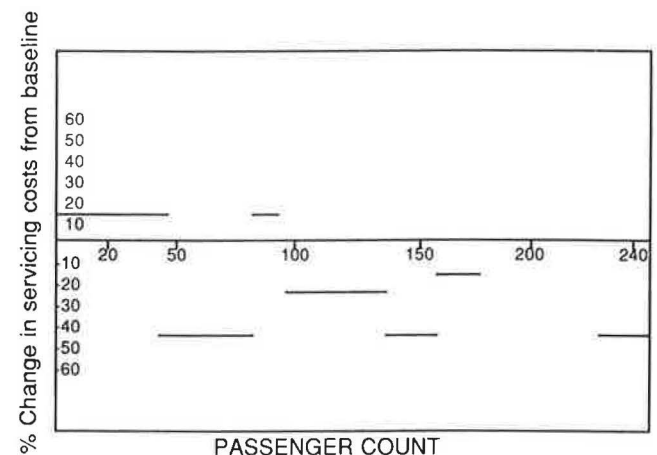


FIGURE 4 Results for 80-seat articulated or double-deck bus (capital cost \$300,000).

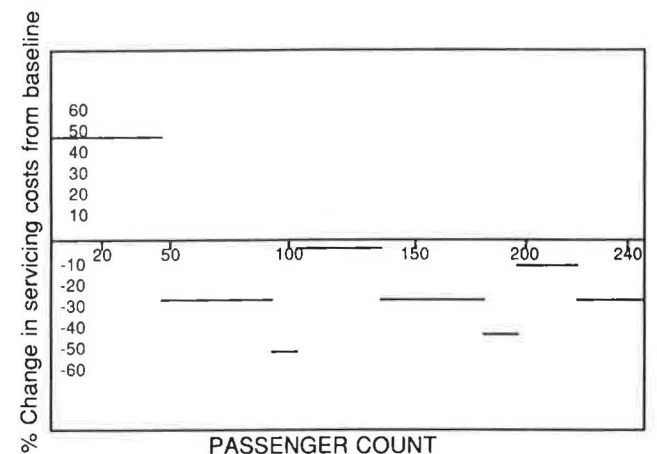


FIGURE 5 Results for 100-seat articulated double-deck bus (capital cost \$500,000).

demand, the relative cost of the higher-capacity bus drops by 43 percent compared with that of the standard bus option. As the number of passengers increases, there is an oscillation between regimes of higher (relative) cost and lower (relative) cost with the magnitudes of savings (in terms of cost differences) decreasing with increasing passenger demand.

The results shown in Figures 4 and 5 suggest that in comparison with a standard bus, the regimes of higher cost are less frequent with the larger-capacity bus units and the percentage cost savings are always higher. As the capital cost and number of seats increase (Figure 5), the initial difference between the use of higher-capacity vis-à-vis standard coach increases.

In the case of the articulated double-deck bus (\$500,000 capital cost, 100 seats), the initial penalty for using it for low passenger traffic is 46 percent for the first 45 passengers (compared with only 17 percent for the 80-seat, \$300,000 bus shown in Figure 4). However, in comparison with the standard coach, after the first 45 passengers, it is always cost-efficient to use the 100-seat jumbo bus. Under conditions of steady and high demand, the 100-seat bus would be a good choice for high-density corridor routes. However, there are only a limited number of such routes in Canada.

Selected results of the route supply and cost model are shown in Figure 6 for the Montreal-Ottawa route. As expected, the standard bus produces the highest cost per passenger-kilometer (e.g., at 70 percent load factor, 3.84 in 1982 dollars). The higher-density seating option of 80 seats for the articulated or the double-deck bus produces the lowest unit cost per passenger-kilometer. Use of the 80-seat articulated (or double-deck) bus is nearly 35 percent more efficient than the standard coach. The articulated double-deck bus (100 seats) has about the same unit cost as the 80-seat high-density seating option for the articulated or the double-deck bus options.

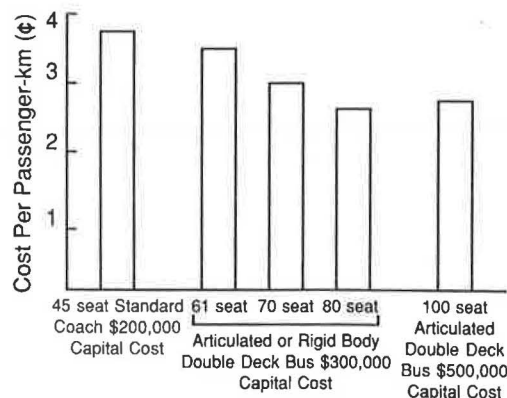


FIGURE 6 Cost-efficiency of bus options for Montreal-Ottawa route (load factor = 70%, 1982 dollars).

At lower but uniform load factors, the relative cost-efficiencies of bus options would be similar to the 70 percent load factor case. Relative cost efficiencies of the bus options can be studied by calculating load factors that result in equal cost per passenger-kilometer (Table 6). As expected, compared with the standard bus, higher-capacity buses require lower load factors to maintain equal cost per passenger-kilometer.

However, it should be noted that, in the case of the articulated double-deck bus (100 seats), it would be difficult to maintain reasonably high load factors on a number of routes. Therefore such high-capacity buses are cost-effective on fewer routes than other bus alternatives.

TABLE 6 LOAD FACTORS FOR EQUAL COST PER PASSENGER-KILOMETER

Technology Option	Cost Per Passenger-Kilometer in ¢ (1982 dollars)	Load Factor (%)
45-seat standard coach (\$200,000 capital cost)	3.8	70
Articulated or rigid double-deck bus (\$300,000 capital cost)		
61 seats	3.8	61.7
70 seats	3.8	53.4
80 seats	3.8	46.1
100-seat articulated double-deck bus (\$500,000 capital cost)	3.8	47.9

All large-capacity buses assessed in this study indicate significant potential to reduce the cost of serving demand in the Quebec-Windsor corridor. By adopting high-capacity buses, peaks in travel demand can be served while attractive frequencies are maintained. However, in cases in which the frequency of service is to be reduced because of lower demand, passenger demand would be adversely affected. Therefore these high-capacity buses are best suited to well-traveled routes on which the number of passengers per departure during peak periods is more than the capacity of the standard bus.

CONCLUSIONS

Intercity bus carriers have come to realize that innovations in bus design are needed to reduce costs and enhance passenger as well as cargo revenue potential. Passengers today expect a smooth-riding, quiet, and comfortable mode of surface travel. Thus there is a need to upgrade the design of the highway bus in respect to costs (mainly labor and fuel costs) and ride comfort (i.e., in terms of mechanical noise and vibration, transmission roughness, ventilation, temperature, seating, and on-board amenities). A number of options, namely the articulated, double-deck, and articulated double-deck bus technology options, examined have the potential to satisfy these requirements to varying degrees compared with the existing standard bus. To use high-capacity articulated buses, length restriction laws in the Quebec-Windsor corridor (and possibly elsewhere) have to be relaxed and replaced by requirements of vehicle maneuverability.

Specific conclusions arising from cost-efficiency analyses follow.

1. An articulated or double-deck high-capacity bus always produces lower cost of transportation per seat-kilometer vis-à-vis the standard (45-seat) coach on routes on which passenger demand per departure exceeds the capacity of the standard coach.

2. The introduction of any one of the large buses investigated here would lower total costs on all of the six routes (within the Quebec-Windsor corridor) that were included in this study. In general, the higher the capacity of the bus, the lower is the unit cost—provided that seating density is comparable. The 80-seat articulated or double-deck bus is nearly 35 percent more cost-efficient than the standard coach. The 100-seat articulated double-deck bus (with somewhat greater space per passenger) is also nearly 35 percent more cost-efficient than the standard bus.

3. For comparable seating density configurations, the highest reduction in cost is achieved with the use of articulated double-deck bus units. However, only a small number of routes have sufficient travel density for cost-effective application of this option. Also, there could be operational constraints. Consequently, it is doubtful that this type of bus will be accepted by carriers. The choice between the rigid body double-deck bus and the articulated bus would be an operational one because both are equally efficient for the corridor routes studied.

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