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SERVICE AND COST COMPARISONS OF BUS RAPID TRANSIT AND LIGHT RAIL TRANSIT

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Abstract

For medium size urban areas, bus rapid transit (BRT) and light rail transit (LRT) are candidates with the potential to serve hourly volumes of 10,000 to 25,000 passengers. Over the years, there has been much controversy about the relative service level and cost-effectiveness between BRT and LRT for this range of demand. Among other reasons for lack of definitive answers, absence of experience with an extensive BRT has been a major one. However, due to the implementation of the transitway system in Ottawa (Canada), and a number of LRT systems operating in Canada, service and cost data have improved. As a result, analyses of service and cost factors can be carried out with confidence. This paper reports research on comparisons of BRT and LRT under identical conditions. The Ottawa region is used as the basis for service (i.e., travel time, frequency, transfers) and cost comparisons. Service and cost models were developed to enable sensitivity analyses wherein these results are presented and discussed. Conclusions suggest that on the basis of the factors included in the models, and for the demand level studied under identical operating conditions, the BRT system offers superior service and cost-effectiveness as compared to the LRT. However, this conclusion should not discourage the implementation of LRT as a complement to the Transitway system as part of an integrated rapid transit network.

Keywords: Bus rapid transit; Light rail transit; Service level; Cost-effectiveness; Transitway
Topic Area: B1 Public Transport and Intermodality

1. Introduction

For medium size urban areas, public transportation technology and service options exist that are worth exploring from both service and cost-effectiveness perspectives. Bus rapid transit (BRT) and light rail transit (LRT) are options to serve hourly volumes of 10,000 to 25,000 persons.

The relative merits of BRT and LRT in terms of cost and service have been highly controversial owing to gaps in knowledge. A number of reasons exist for divergent views on this subject. For instance, the lack of experience with an extensive BRT system is a major contributing factor to the controversy. However, opportunities are now available for overcoming knowledge gaps in order to compare service and cost factors with confidence. The implementation of the transitway system in Ottawa (Ontario, Canada) and LRT systems in use throughout Canada provide a sound knowledge base.

The objective of this research paper is to compare the service and cost of BRT and LRT under identical conditions. The Ottawa region is used as a case study, including the transitway system.

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Also, a discussion of the potential effects of advanced technology in enhancing the relative position of BRT vis-à-vis LRT is provided.

2. Rapid transit systems for medium size areas

For sustainability reasons, there is a keen interest around the world in rapid transit systems. While in the past, planning studies generally focussed on rail transit systems, at present there is some recognition that bus rapid transit is worthy of attention.

For example, a recent publication of the International Energy Agency (IEA) describes the contribution of BRT system to sustainable transportation (IEA 2002). In a 2001 report, the U.S. General Accounting Office (GAO) illustrated some of the advantages of BRT (GAO 2001). The U.S. Federal Transit Administration (FTA) is actively promoting BRT by publishing a reference guide and advancing a demonstration program (FTA 2002). The Transit Cooperative Research Program of the U.S. Transportation Research Board has published a report of case studies involving BRT (TRB 2003).

Urban transit systems can be characterized by the range of passenger volumes that can be served at a reasonable cost and an acceptable level of service (Nisar and Khan 1992, Khan 1992). In conceptual terms, for low volumes, buses operating on city streets in mixed traffic provide the most efficient option in terms of minimum $/passenger-km. At the other extreme, rail rapid transit, commonly known as a "subway", is the best system for very high volumes from both a cost and service perspectives.

For medium-to-high density areas, the intermediate capacity of advanced light rail transit (ALRT) is suitable. The BRT and LRT systems can be regarded as competitors for medium density urban areas. For specific applications, detailed analyses of cost, service and operational considerations would be required in order to establish the most suitable public transit option. Energy and environmental factors are also important considerations.

2.1 Bus rapid transit

The BRT system is based primarily on an access controlled transitway, also known as a busway. The transitway is an exclusive roadway with its own right-of-way or a roadway within a freeway right-of-way, physically separated from other traffic. Additionally, a freeway lane could be designated for the exclusive use of buses. On arterial roads, a lane can be specified as a BRT facility (Martinelli 1996, Henke 2001, FTA 1998, Ardila 2000). For improving overall operating speed, priority can be given to public transit buses at signalized intersections. Although various types of transitways have been built around the world, the most advanced ones are in Curitiba (Brazil) and Ottawa (Canada). The analyses reported in this paper are based on the Ottawa transitway experience.

Ottawa's rapid transit system is based on transitway technology first opened in 1983. At present, it consists of:

- 26 km of two-way bus-only roadway
- 3 km on the Ottawa River Parkway
- 4 km of bus lanes through the Central Area
- 21 km of bus-only shoulder lanes on the Queensway (a freeway)
- 25 stations
- 6 major downtown stops
- 4 park-and-ride lots.

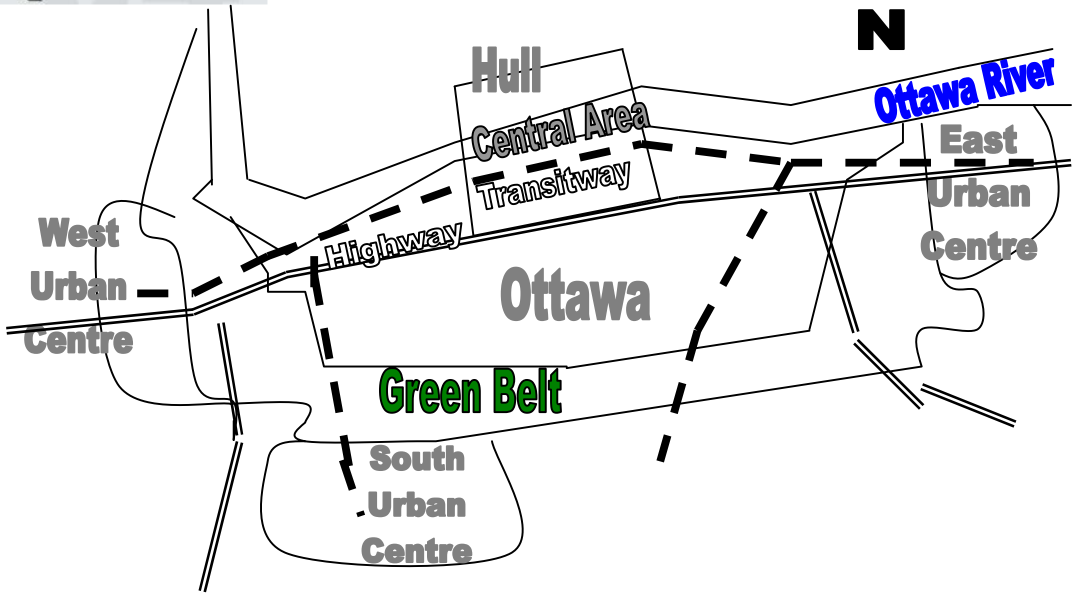

Figure 1: Ottawa (Canada) Transitway

Many stations are located next to major shopping centres or employment sites. A schematic diagram of the Ottawa BRT is shown in Figure 1.

The Ottawa transitway system provides rapid transit service for over 200,000 passenger trips a day. Convenient connections are provided to the intercity train station and the airport (Dillon Consulting Limited 1997, Poole and Orski 2003). The BRT stations offer convenient transfer points with some heated waiting areas, phones, and information displays. Many stations offer vendor kiosks and bike racks.

A transitway facilitates the use of motorbus technology to provide service with a high degree of flexibility in terms of types of operation, routes and schedule changes. The most appropriate configurations are shown in Figure 2.

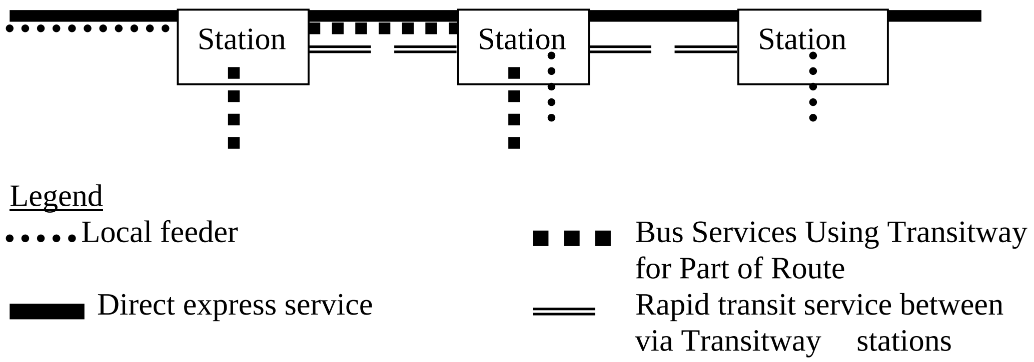

Figure 2: Transitway Services

The transitway enables a rapid transit service to be provided between stations at high frequencies. Passengers can access stations either by walking, using park-and-ride, kiss-and-ride or feeder bus services. Another type of service that can be provided through the transitway is the direct express service comprised of a local feeder and a line haul service without transfers. Attractive features of this service are that a "one-seat" ride is provided, and that, due to its express nature, the bus does not stop at every station. In addition to providing a high level of service to through passengers, the frequency of service at some transitway station is increased.

Transitway systems also support the provision of a third type of operation. An area-wide service can use the transitway as a part of its entire route resulting in enhanced overall speed, frequency of service at transitway stations, and coverage of the wider area. An outcome would be increased ridership and reduction in feeder services (if provided separately). A notable feature of the transitway system compared to LRT is that the same rapid transit facility is used through overlapping the type of services and routes.

2.2 Light rail transit (LRT) as a complement to transitways

Although the focus of this paper is on the comparative benefits of BRT and LRT under identical demand and service conditions, it is useful to point out that both technologies can be planned as complementary integrated systems within the rapid transit network. For example, the City of Ottawa implemented an LRT pilot project in 2001, called the O-Train, as the first step toward an LRT system that would complement the Transitway system (OC Transpo 2003).

The O-train serves a linear corridor with five specially designed stations. The end stations are well connected with the Transitway stations and the intermediate stations are served by bus lines. The train sets, consisting of three coupled cars, are modern streamlined diesel-powered units. The lines are leased from the Canadian Pacific Company and were improved for rapid transit service (OC Transpo 2003).

If the results of the demonstration system are favourable, a larger scale LRT implementation will be considered with the objective to expand the rapid transit network in Ottawa (OC Transpo 2003).

2.3 Light rail transit (LRT) system for comparative analysis

For a comparative analysis of BRT and LRT systems, Ottawa service conditions are assumed. The LRT system assessed here assumes an exclusive right-of-way in the outlying areas and protected right-of-way or elevated/subway operations in the central business district. The trains consist of coupled cars. Fare is collected off-the-vehicle.

The services provided by the LRT-based system, shown in Figure 3, are between stations. Access to the stations is by walking, feeder services, intermodal transfer, kiss-and-ride and at some locations, by park-and-ride. Although the LRT system provides a comfortable ride to all users, those passengers whose origin and destination are within walking distance enjoy a high overall level of service.

3. Framework for the study of cost and service factors

The methodological framework for the estimation of cost and service factors is presented in Figure 4. This figure suggests that the main variables that affect costs, service levels and revenues are demand, technology and system-related factors. However, for comparative analysis, identical demand levels are assumed.

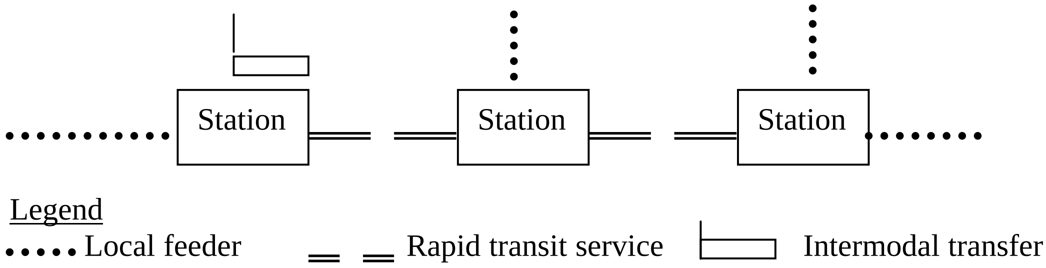

Figure 3: LRT Services

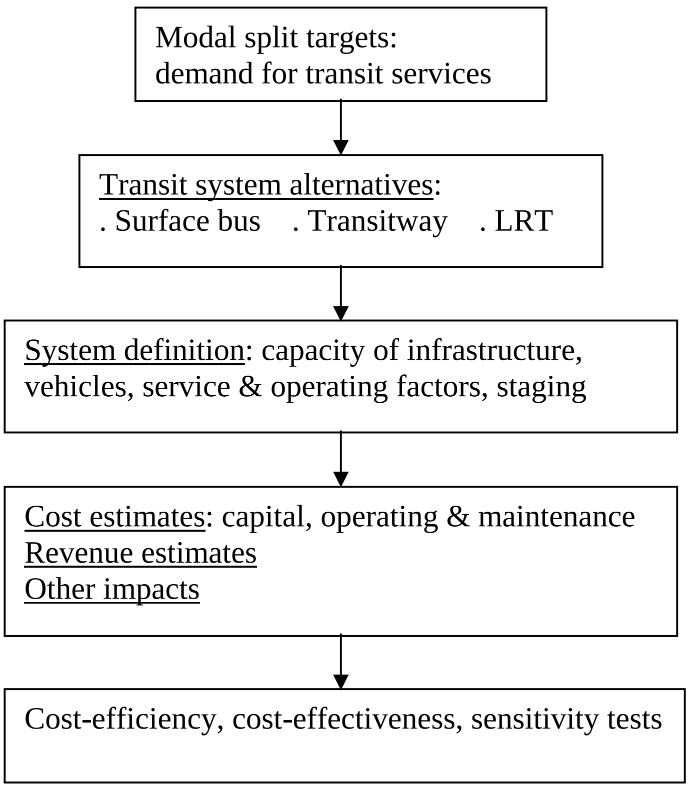

Figure 4: Methodological Framework

Starting from modal demand targets for transit patronage, the transit system alternatives can be delineated. For medium size urban areas such as Ottawa, two options for rapid transit service are BRT and LRT. The next step involves system definition in terms of infrastructure, vehicles, service and operating factors (i.e., speed, frequency, comfort, etc.) and staging considerations.

Cost estimates are developed in terms of capital, operation and maintenance costs. Revenues are estimated from assumptions about fares to be charged and ridership forecasts. Please note that revenues are not discussed in this paper. Other impacts, including impacts on land use and the environment are also required for decision-making. From these analytical outputs, evaluations can be performed in the form of cost-efficiency (i.e., cost/passenger-km, cost/passenger) and cost-effectiveness (i.e., the achievement of service and other objectives for given cost levels).

Among other variables, the level of service offered by public transit systems, the fares that users are willing to pay and the system capacity are notable. The level of service for a public transit system can be described in terms of its attributes, as perceived by users. These are: overall door-to-door travel time/speed, service frequency, access to system, "one-seat ride" (if permitted by technology), short walk to station/stop, ride quality, schedule adherence and personal (out-of-pocket) costs.

Operators incorporate these factors in planning rapid transit systems. However, from an operator's perspective, meeting an adequate level of service requirement on an area-wide basis has to take into account cost constraints.

The capacity of a rapid transit service, based on the safe physical accommodation of vehicles (in controlled conditions) on a segment of lane/track, is an important planning consideration. In the case of buses operating on an arterial road, the quality of traffic flow affects the capacity of transit service.

Table 1 shows generalized estimates of capacity and overall average door-to-door speed for selected urban transit systems. The capacity estimates are based on the assumption of high utilization and efficient operation serving a high patronage level. The capacity estimates reflect the passenger handling capabilities of the various components of the system including stations (Armstrong-Wright 1986, Zargari and Khan 1999).

The estimation of lane/track capacity is influenced by the size of the vehicle itself, service frequency, the length of the train (for LRT) and the station or platform length. The differences among capacities reflect assumptions of vehicle capacity, load factors and comfort criteria.

Table 1: Capacity and Average Speed

	Range of Avg. Speed (door-to-door) (Km/h)	Lane/Track Capacity: Passengers/h	
		Theoretical	Estimates for Ottawa
Bus-only lane	15-18	Up to 20,000	15,000
Transitway	15-40	Up to 30,000	16,000
LRT(Surface exclusive)	15-40	20,000-36,000	19,200

Sources: Average speed and theoretical capacity are from Ardila (2000), Armstrong-Wright (1986) and Zargari and Khan (1999). Estimates for Ottawa are from Nisar and Khan (1992), Khan (1992), and Zargari and Khan (1999).

4. Comparison of service levels

A number of analyses were required in order to estimate the most important elements of the level of service, namely the average overall (door-to-door) speed (Figure 5). In the case of trips that would be made by the transitway, a check was made on their origins and destinations to establish whether express service provision criteria could be met. In areas where threshold demand for express service was not met, the provision of general services was assumed. For all passengers, the applicable components of travel times were estimated. From this, the weighted average overall speed was computed.

Transitway

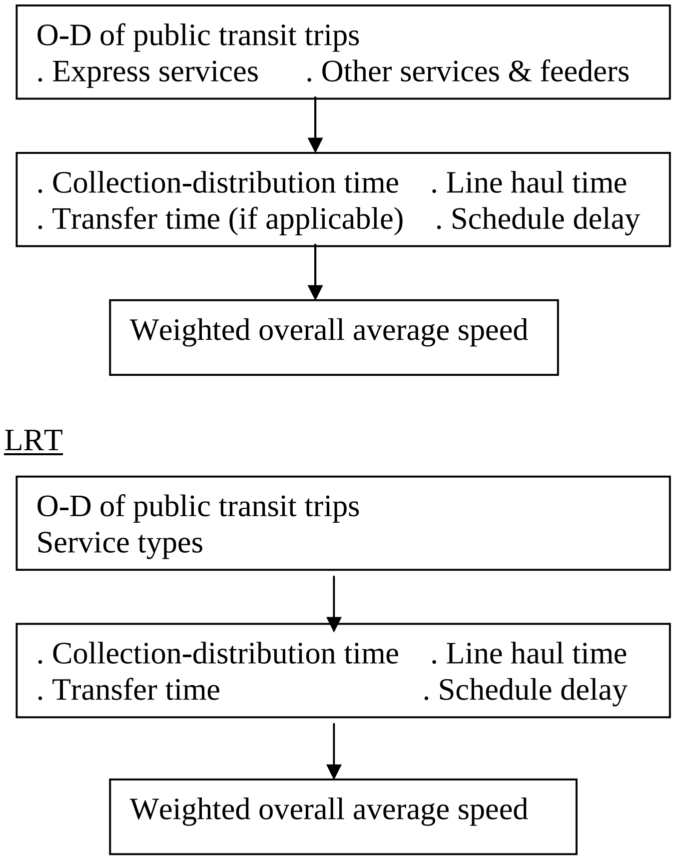

Figure 5: Door-to-door Speed

The procedure followed for the estimation of overall average speed for the LRT system was generally similar to the transitway. The exceptions are that a number of services are not involved since these cannot be offered by the LRT system (i.e., express door-to-door service, area-wide service using transitway for part of the route).

Table 2 presents the results of the analyses on origin-destination trip time. For a medium density urban area such as represented by Ottawa, the transitway system offers a lower travel time than the LRT. Also, the non-ride time for transitway service is much lower than for LRT. Studies suggest that transit users place a much higher importance on the reduction of out-of-vehicle time vis-a-vis in-vehicle time (Zargari and Khan 1999).

Table 2: Origin-Destination Trip Time

	In-vehicle (ride) time	Out-of-vehicle (non-ride) time	Total trip time
Transitway	39.7 min (78.7%)	10.7 min (21.3%)	50.4 min (100.0%)
LRT	38.6 min (66.7%)	19.3 min (33.3%)	57.9 min (100.0%)

5. Cost comparisons

The methodology developed for producing cost estimates for the transitway and LRT systems is shown in Figure 6. From estimates of daily passengers and service requirements, a system configuration was defined in terms of route length, vehicle type(s), cars/train (for LRT), station spacing and trip length. System (technical) specifications were required in the form of acceleration/deceleration characteristics, maximum speed, turnaround time and station stop time.

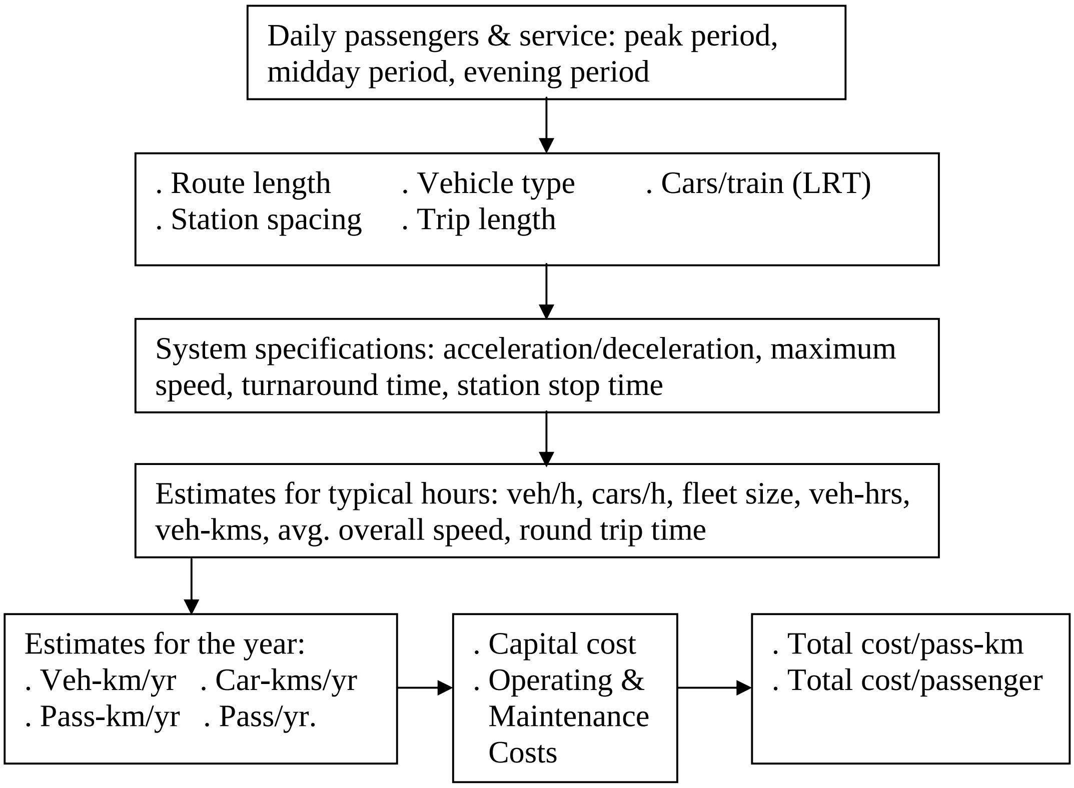

Figure 6: Cost Estimation for Transitway and LRT

Estimates for typical hours (e.g., peak hours) were developed for the following variables: vehicles/h, cars/h (for LRT), fleet size, vehicle-hour, vehicle-km, overall average speed, and round trip time. The next step required the calculation of veh-kms/yr, car-kms/yr, pass-kms/yr, and pass/yr. Through the use of applicable unit costs, the following cost estimates were developed: capital cost, operating and maintenance cost, total cost/pass-km and total cost/passenger.

The results presented in Table 3 for a 15 km route length suggest that the transitway offers lower cost/passenger than the LRT. It can also be observed that, as compared with the transitway, the capital costs of LRT form a high proportion of the total cost. These results agree with the findings of other studies on the comparisons of BRT and LRT under identical conditions (Gravel and Bowes 1997, Leicester 1999).

Table 3: Cost Comparisons (in 2000 Canadian $) for 15,000 Passengers/Hour and 15 km Route Length

System	Capital Cost ($/passenger)	Operation & Maintenance ($/passenger)	Total ($/passenger)
Transitway			
12.2m bus	0.74	0.91	1.64
18.3m bus	0.70	0.64	1.34
LRT			
Max. train length Of 5 cars/train	1.85	0.42	2.27

6. Cost-effectiveness comparisons

Evaluation criteria for public transit options have varied from study to study. The Ottawa-Carleton rapid transit study, in addition to cost and service, considered factors that affect residents of the region in their homes, impacts on the broader urban environment, other traffic effects, and ease of incremental development of services (Khan 1992).

A World Bank study suggested a number of effectiveness criteria, including: air pollution, noise, visual intrusion, and overall speed (Armstrong-Wright 1986). The evaluation criteria used in the case of Calgary's LRT South Corridor included, in addition to the main public transit objectives, operational impacts, and social and environmental impacts. Although all factors noted here are relevant, the most frequently used cost-effectiveness indicator is $/pass-km versus door-to-door average travel speed.

For a comparative study of cost-effectiveness, the computed cost estimates per passenger-km and the overall average speed can be examined in Table 4. The results indicate that the transitway is more cost-effective than LRT.

Table 4: Cost-Effectiveness -- Cost vs. Overall Average Speed

	Transitway	LRT
Cost/pass-km (2000$)	0.11	0.15
Average speed (km/h)	38.4	36.1

7. Effectiveness of applying advanced technologies

LRT systems have already benefited from computer and communication technology applications. The cost and service characteristics of the LRT system modelled in this research have taken such applications into account.

However, in the case of BRT, the technology for vehicle location, tracking the minute-by-minute performance of buses, fleet control, user information systems, and computer-communication assisted maintenance planning are evolving rapidly. One component of Intelligent Transportation Systems (ITS), namely, automated vehicle location and control system, is gaining wide acceptance in the bus transit industry. Advanced user information systems have become available that can provide bus arrival times of the next bus and other service information. The end results will be favourable user perception of service and also efficiency and productivity gains for bus rapid transit operators.

Advanced bus engine technologies are already in service or at the demonstration stage. Notable among these are the diesel-electric hybrid and fuel cell engines. The hybrid technology has low emission characteristics and the hydrogen fuel cell engine has zero emissions. Even if emissions from the primary energy source are traced, there is a very high degree of emission reduction compared to a diesel engines. Additionally, a fuel cell engine has low noise emissions.

8. Conclusions

For medium density urban areas, BRT is a serious alternative to LRT. Depending upon site-specific conditions, the BRT option might be the best choice from the perspective of level of service offered to users as well as cost-effectiveness. On the basis of the analyses reported here, the BRT system ranks ahead of LRT under identical demand and service conditions. However, this conclusion should not discourage the implementation of LRT as a complement to the Transitway system in order to form an integrated rapid transit network.

The use of ITS technologies will further improve the cost and service of BRT. The use of fuel cell and hybrid engine technologies will enhance the environmental benefits of BRT. BRT systems can be implemented in a short period of time with relatively modest initial costs. Also, such systems enable the matching of supply and demand with relative ease.

On the other hand, for short compact corridors with right of way constraints, LRT service is an attractive option, although it has higher initial costs and requires a longer period of time for its implementation than bus rapid transit.

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