COST-EFFICIENCY AND SERVICE LEVEL COMPARISONS OF TRANSITWAY AND LIGHT RAIL TRANSIT

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1.1 INTRODUCTION

For medium density urban areas and medium density corridors, public transportation technology and service options exist that are worth exploring from both cost-efficiency and level of service perspectives. The bus transitway, light rail technology (LRT), and advanced light rail technology (ALRT) are worth exploring as options to serve hourly volumes of 10,000 to 30,000 persons.

The relative merits of LRT and transitway options in terms of cost-efficiency and service levels have been highly controversial owing to gaps in knowledge. A number of reasons exist for lack of definitive answers on this subject, including lack of experience with an extensive transitway system. However, opportunities are now available for overcoming knowledge gaps and comparing cost-efficiency and service levels with confidence. The implementation of the transitway system in the Ottawa-Carleton region (Ontario, Canada), and the development of a number of LRT systems elsewhere in Canada provide such an opportunity. Also, increasing applications of advanced technologies to bus transit can now provide a basis for studying effects in terms of cost reduction and service improvements.

The objective of the research supervised by the author and reported in this paper is to compare cost-efficiency and service levels for the LRT and transitway systems, incorporating cost and service attributes of the transitway system serving the Ottawa-Carleton region. Also, to go beyond an analysis of the current cost and level of service estimates, this paper discusses changes in these factors that could be brought about through advanced technology applications.

2. RAPID TRANSIT SYSTEMS FOR MEDIUM DENSITY AREAS

Urban transit systems can be characterized by a range of passenger volumes that could be served at an acceptable level of service (Nisar, Khan and Johnson, 1989; Nisar 1989). In conceptual terms, for low volumes, bus operating on city street in mixed traffic is the option for minimum

$/passenger-km. On the other extreme, rail rapid transit, commonly known as a "subway", is the cheapest system for very high volumes. For medium density areas, the transitway, the light rail transit (LRT) and the highly automated intermediate capacity advanced light rail transit (ALRT) become candidates. The ALRT is preferred to transitway as well as the LRT in areas with higher volumes than those required to support the LRT option. The transitway and the LRT can be regarded as competitors for medium density urban areas. For shorter corridors in compact cities with very high right of way costs, the LRT might show lower operating costs than bus rapid transit system.

For specific applications, detailed location-specific analyses of cost-efficiency, and service and operational considerations would be required in order to establish the most suitable public transit option. The energy and environmental factors are also important considerations.

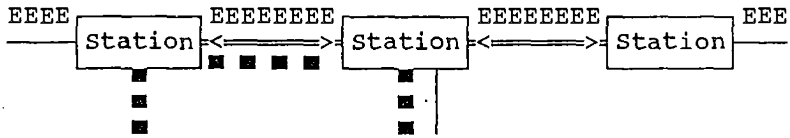
2.1.Bus Rapid Transit

A transitway, also known as a busway, is an exclusive roadway or a designated lane of a freeway for the exclusive use of buses and/or other high occupancy vehicles (HOV). On arterial roads, a lane can be specified for the exclusive use of buses. The Ottawa-Carleton transitway and the East and South busways in Pittsburgh (U.S.A.) are built in a separate right-of-way that is used exclusively for buses. Such facilities provide high capacities and offer high speed travel.

A second type of transitway is a roadway within a freeway right-of-way but is physically separated from other traffic. Such transitways are in operation in Houston, Washington, D.C., and Los Angeles. There are still other types of transitway facilities which provide lower capacity and are not regarded as competitors to the LRT. In downtown areas, before exclusive right-of-way can be provided for bus operations, bus exclusive lanes have to be used.

A transitway enables the motor bus technology to provide services with a high degree of flexibility in terms of types of operation, routes and schedule changes. Most appropriate configurations are shown in Figure 1.

The transitway enables a rapid transit service to be provided between stations at high frequencies. Passengers can access stations by walking, park-and-ride, kiss-and-ride or feeder bus service. 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 any transfer. Attractive features of this service are that "one-seat" ride is provided and that due to its express nature, it does not stop at every station. In addition to providing a high level of service to through passengers, the frequency of service at some stations of the transitway is increased.



Legend

—— Local feeder	EEEE Direct express service via transitway
■ ■ ■ Bus service using transitway for part of the route	<==> Rapid transit service between stations

Figure 1: Transitway Services

Transitway also enables the provision of a third type of service. An area-wide service can use the transitway as a part of its entire route -- resulting in enhanced overall speed, enhanced frequency of service at transitway stations, and a coverage of the wider area. An outcome would be increased ridership and reduction of the feeder services (if provided separately).

A notable feature of the transitway over the LRT is that the same rapid transit facility is used by overlapping type of services and routes.

2.2. Light Rail Transit (LRT) System

The LRT system to be assessed here is the one with the exclusive right-of-way in the outlying areas and protected right-of-way or elevated/subway operations in central business districts. The trains consist of coupled cars. Fare is collected off-the-vehicle. The services provided by the LRT-based system, shown in Figure 2, are between stations. Access to stations is by walk, feeder services, intermodal transfer, kiss-and-ride and park-and-ride. Although the LRT provides a comfortable ride to all users, a high overall level of service is enjoyed by those passengers whose origin and destination are within walking distance.

3. FRAMEWORK FOR THE STUDY OF COST AND SERVICE FACTORS

3.1. General Description

The methodological framework for the estimation of cost and service factors, presented in Figure 3, suggests that the main variables that affect costs, service levels and revenues are technology and system-related. Starting from modal demand targets for transit patronage, the transit system alternatives can be delineated. For medium size urban areas such as Ottawa (Canada), three options are: surface bus, transitway-based bus rapid transit, and the 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.

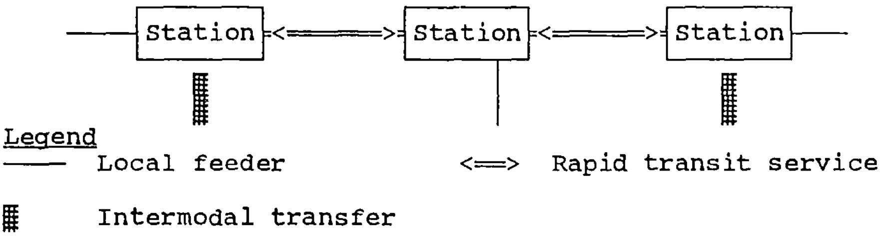


Figure 2: LRT Services

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. Other impacts such as those on land use and the environment are also required for decision-making. From these outputs of analyses, 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, level of service offered by public transit systems, fares that users are willing to pay and capacity of systems are notable. The level of service for a transit system can be described in terms of its attributes as perceived by users. These are: overall door-to-door 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 have to take these factors into account in planning rapid transit systems. However, from an operator's perspective, meeting adequate level of service requirement on an area-wide basis has to take into account the cost constraints.

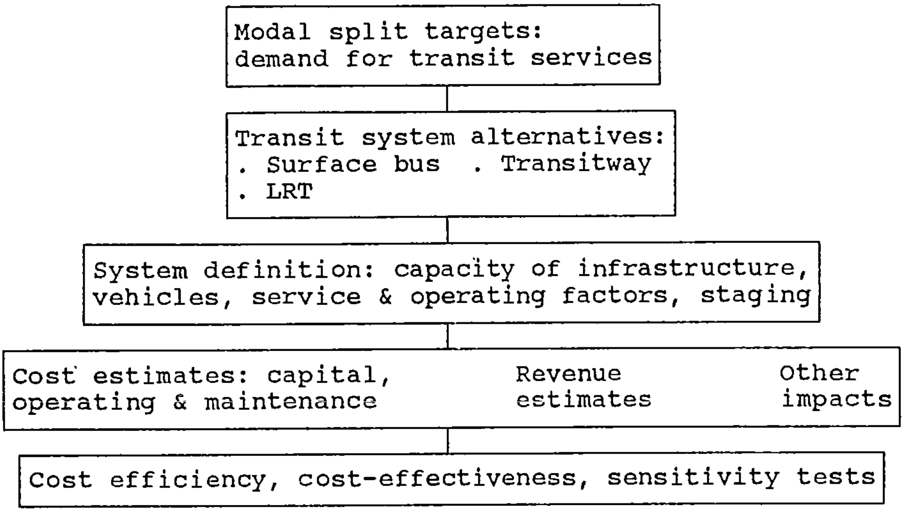


Figure 3: Methodological Framework

Capacity of a rapid transit service, based on safe physical accommodation of vehicles (in controlled conditions) on a segment of lane/track, is an important planning consideration. In the case of bus in mixed traffic, the quality of traffic flow, of course, 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, efficient operation serving a high patronage level. The capacity estimates reflect the passenger handling capabilities of the various components of the systems --including stations. The estimation of lane/track capacity is influenced by the size of the vehicle itself, service frequency, length of train (for LRT) and the station or platform length. The differences among capacities reflect assumptions of vehicle capacity, load factors and comfort criteria.

4. COMPARISON OF SERVICE LEVELS

A number of simulations were required in order to estimate an important element of the level of service -- the average overall (door-to-door) speed (Figure 4). 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 established.

Table 1: Urban Transit Capacity & Overall Average Speed

	Avg.	Lane/Track Capacity: Passengers/h	
	speed	Theoretical*	Ottawa-Carleton**
Bus in mixed traffic	10-20 km/h	10,000-15,000	
Bus-only lane	15-18	15,000-20,000	
Transitway	15-30	upto 30,000	16,000
LRT (surface exclusive)			
3-6 cars/train	15-25	20,000-36,000	19,200

* Armstrong-Wright, 1986 ** RMOC, 1976

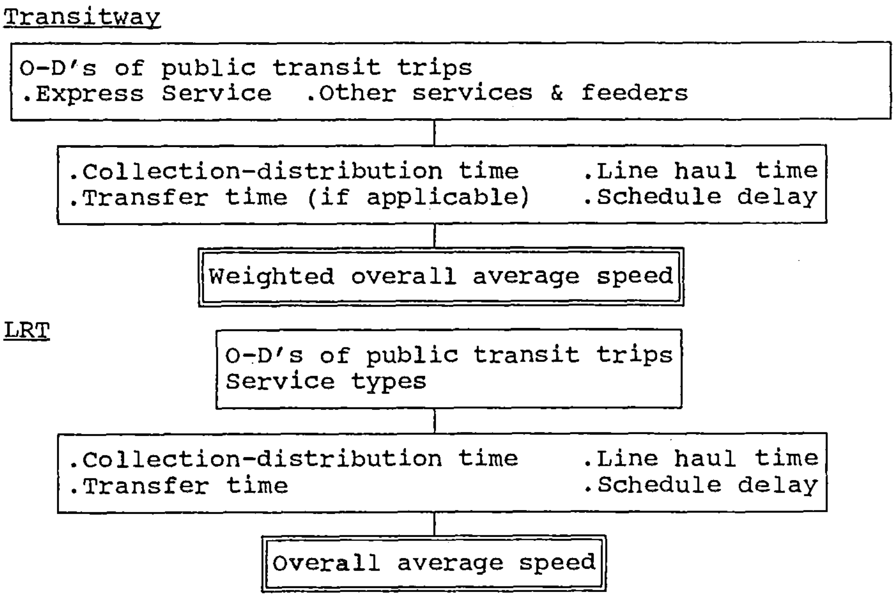


Figure 4: Door-to-Door Speed

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 examples of simulation results on origin-destination trip time. For a medium density urban area represented by the Ottawa-Carleton region, the transitway offers a lower time than the LRT. Also, the non-ride time for transitway 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.

Table 2: Origin-Destination Trip Time: Simulation Results*

	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%)

* Nisar, 1989

5. LIFE CYCLE COST COMPARISONS

The methodology developed for producing cost estimates for the transitway and LRT is shown in Figure 4. From estimates of daily passengers and service requirements, system configuration is 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, maximum speed, turnaround time and station stop time.

Estimates for typical hours (e.g., peak hours) were developed for the following variables: vehicles/h, cars/h (for LRT), fleet size, vehicle-hours, vehicle-km, overall average speed, and round trip time. The next step required the calculation of veh-km/yr, car-km/yr, pass-km/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.

Results presented in Table 3 for 6 km and 15 km route lengths suggest that the transitway offers lower cost/passenger than the LRT. It can also be observed that, as compared with the transitway, LRT's capital costs form a high proportion of the total cost.

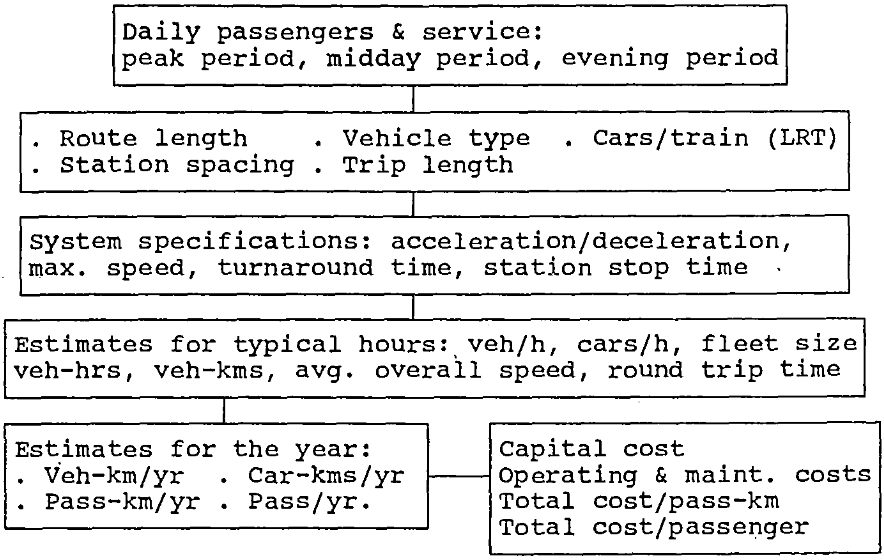


Figure 5: Cost Estimation for Transitway and LRT

Table 3: Cost Comparisons (1987$)*

	Capital cost	Operating & Maint. cost	Total
(a) 15,000 passengers/hour, 6 km route length			
Transitway			
40 ft bus	$0.22/pass	$0.28/pass	$0.50/pass
60 ft bus	0.21/pass	0.20/pass	$0.41/pass
LRT			
max. train length of 5 cars/train	0.59/pass	0.13/pass	$0.72/pass
(b) 15,000 passengers/hour, 15 km route length			
Transitway			
40 ft bus	$0.53/pass	$0.65/pass	$1.18/pass
60 ft bus	0.50/pass	0.46/pass	$0.96/pass
LRT			
max. train length of 5 cars/train	1.33/pass	0.30/pass	$1.63/pass

* Nisar, 1989

6. SERVICE AND COST-EFFICIENCY COMPARISONS

Evaluation criteria for public transit options have varied from study to study. The Ottawa-Carleton rapid transit study, in addition to cost and capacity, 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 (Regional Municipality of Ottawa-Carleton, 1981). A World Bank study suggested effectiveness criteria to include 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, social and environmental impacts.

For a comparative study of cost-effectiveness, the available 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 vs. Overall Average Speed*

	Transitway	LRT
Cost/pass. km (1987$)	0.07-0.13	0.12-0.14
Avg. speed km/h	18.52-38.38	13.78-36.12

* Nisar, 1989

For further study of cost-effectiveness, additional effectiveness criteria are used. Table 5 shows costs (in $/pass. km) and effectiveness for a number of public transit options. The costs for the transitway and LRT are the mid points of ranges shown in Table 4. Costs for bus in mixed traffic and bus in reserved lanes are inferred from relative position of costs given in the World Bank study and the transitway costs shown in Table 4. The subjective measures of effectiveness are assigned on the basis of a knowledge of these systems. Estimates of speed are sourced from Table 4 and from the World Bank study.

A relative value method enabled the transformation of effectiveness statements into relative values (i.e., very good = 1.0, good = 0.75, average = 0.5, poor = 0.25). The ranks assigned to criteria are transformed into weights, which in turn enabled the estimation of weighted effectiveness of each option in satisfying each criterion. A summation of weighted effectiveness of criteria gives an index of the effectiveness of each option. These numbers are plotted against costs in order to obtain a mapping of the cost-effectiveness (Figure 6).

Table 5: Cost-Effectiveness Example

		Bus in mixed traffic	Bus in reserved lanes	Transitway	LRT
Cost/pass. km		0.054+	0.054+	0.10*	0.13*
Effectiveness					
Rank	Criterion				
1	Safety	average	average	good	good
2	Avg. speed (km/h)	11.0	16.5	28.5*	25.0*
3	Emissions	poor	average	good	v. good
4	Visual intrusion	good	good	good	average
5	Noise	average	average	good	average
6	Desirable land use impact	poor	average	good	good

+ Estimated on the basis of relative cost figures reported in Armstrong-Wright (1986) ** From Table 3 (midpoints)

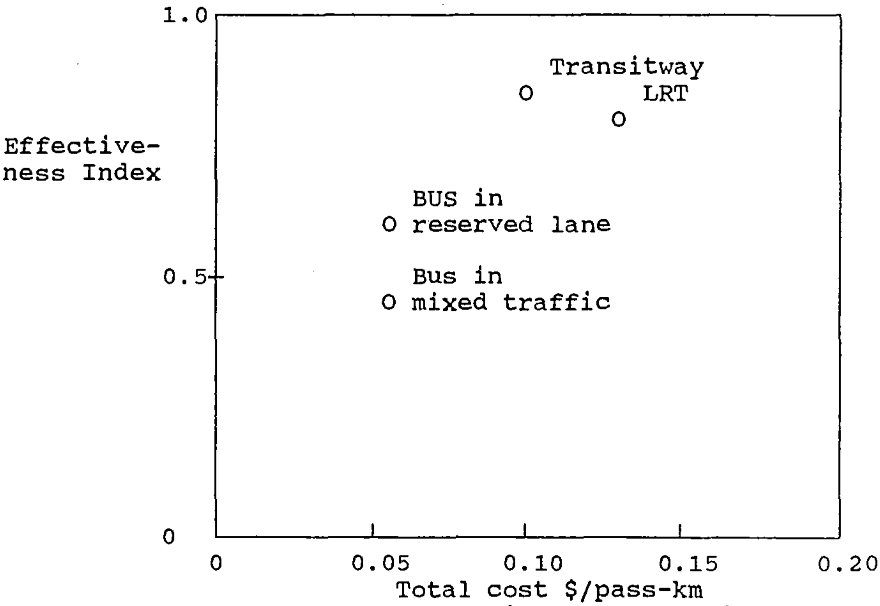


Figure 6: Cost-Effectiveness Comparisons

7. EFFECTS OF APPLYING ADVANCED TECHNOLOGY

The LRT system has already benefitted from computer and communication technology applications. The cost and service characteristics of the LRT system modelled in this research have taken into account such applications. However, in the case of bus rapid transit, 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 the intelligent vehicle highway systems (IVHS), namely, automated vehicle control system, is intended for efficient transport management of fleets such as bus transit. The end results will be favourable user perception of service and also efficiency and productivity gains for bus rapid transit.

8. CONCLUDING REMARKS

For medium density urban areas, bus rapid transit is a serious alternative to the LRT system. Depending upon site-specific conditions, the transitway options might be the best choice from the perspectives of cost-efficiency, level of service offered to users and overall cost-effectiveness. On the basis of the analyses reported here, the transitway ranks ahead of the LRT for the Ottawa-Carleton region. The use of evolving new advanced technologies such as automatic vehicle location and control will further improve the cost and service of bus rapid transit. Transitway can be implemented in a short period of time with modest initial costs. Also, it enables with ease, the matching of supply with demand. On the other hand, for short compact corridors with right of way constraints, the LRT is an attractive option, although it has higher initial costs and requires a longer period of time for its implementation than bus rapid transit.

9. ACKNOWLEDGEMENTS

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