TRANSITWAYS OFFER SUPERIOR LEVEL OF SERVICE AND ECONOMIC EFFICIENCY

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INTRODUCTION

In the early 1960s, Meyer, Kain and Wohl compared the technologies of bus and rail transit and highlighted merits of bus transit for low to medium density urban areas (1). Then in 1969, Deen and James examined the relative costs of bus and rail and concluded that for lower volume routes, bus transit systems are indeed attractive (2). Still other studies in the early 1970's have examined the potential for bus rapid transit (3). In the sixties or even in the seventies, there was very little experience with bus rapid transit and all cost and service performance measures were mere estimates based on theory alone. In the 1970s, numerous urban areas in North America opted for light rail transit (LRT) (operating mainly on surface routes) as their primary system for public transportation, and relying upon bus feeders.

Recently, actual experience of Ottawa (Canada) with its rapid transit system based entirely on the motor bus, Pittsburgh's (U.S.A.) East Busway (corridor) and other transitway type of facilities operating in American cities, namely Washington, D.C., Los Angeles and Houston, although of limited scope, have created a renewed interest in the merits of bus rapid transit. The Bus World journal has favourably reviewed Ottawa's busway in a feature article (4). The American Public Transit Association (APTA) has published a special report describing merits of transitways (5). Kain, in a recent article has called for a reorientation of transit investment priorities in the direction of bus rapid transit (6).

This paper provides further insights in the comparative assessment of bus transitways and LRT-based systems (for medium size urban areas) in terms of level of service and economic efficiency. This comparative assessment does not extend to the intermediate capacity rail rapid transit system such as the Advanced Light Rail Transit (ALRT) system of Vancouver.

TRANSITWAY AND LIGHT RAIL SYSTEM CHARACTERISTICS

Transitways

Transitways, also known as busways are a relatively new alternative to conventional urban transportation options. In general, a transitway is an exclusive roadway or a lane of a roadway used specifically for buses and other high occupancy vehicles (HOV) (5). A bus rapid transit consisting of collection/distribution, transfer and line haul facilities uses the exclusive facility on a separate right of way for line haul movement. The exclusive facility could be on a freeway right of way but separated from other freeway lanes. For rapid movement of high occupancy buses, such a facility may even exclude other (smaller) HOVs such as van pools. In some instances, a freeway or arterial lane that is not physically separated from the other traffic lanes, could be used exclusively for bus transit as a concurrent flow or contraflow lanes.

Major North American transitways are listed in Table 1. The Ottawa-Carleton System, when fully developed, will be the most extensive in North America. According to the official plan of the Ottawa-Carleton Region, rapid transit is to be developed in five major corridors including one that links Ottawa with its twin city of Hull and that priority should be given to construction of rapid transit over major new road construction and road widening (7). As a part of planning studies, technical evaluations examined both intermediate capacity and high capacity rapid transit technologies and recommended that transitways and light rail technologies should be subjected to more detailed analysis in subsequent stages of the rapid transit development program.

In 1980, a 10 year construction program was established, comprising of nine projects whose total length is approximately 31 km. It was decided to use bus technology initially, operating on exclusive transitways and in reserved bus lanes on existing streets within the Central Area, including at grade and grade-separated alternatives.

Previous studies have described numerous way of providing the door-to-door service on bus rapid system (2,3). In order to maximize the flexible service potential of the bus technology, the most appropriate configuration of the system is shown in Figure 1. The various types of services are defined below:

- Transitway rapid service between stations (similar to a rail rapid service),
- Direct express service via transitway, providing the local feeder as well as the line haul service without transfer,
- Transit service using the transitway for a part of the overall route, and
- Local service to stations provided by feeders.

Four types of urban bus services relate to transitway. For users that can walk to the station or others that use the kiss

Table 1
Major North American Exclusive Busways

Facility/City	Year of Implementation	Length (km)	Passengers Served
Exclusive facility on separate right of way			
. Ottawa-Carleton West Transitway	1983	12.7	9,000 peak hr. 115,000 daily
East Transitway	1983	7.4	9,000 peak hr. 95,000 daily
. Pittsburgh, PA. East Busway	1983	11.0	5,590 peak 28,500 daily
South Busway	1977	5.6	2,950 peak 18,000 daily
Exclusive facility on Freeway right of way			
. Houston, Texas I-10 (Katy)	1984	18.5 (one way)	4,114 peak hr. 15,900 daily
I-45 (North)	1979	15.5 (one way)	4,055 peak hr. 14,000 daily
. Los Angeles, CA I-10 (El Monte)	1973	17.7	8,000 peak hr. 43,000 daily
. Washington, D.C. I-395 Shirley	1969	17.7 (one way)	17,260 peak hr. 63,486 daily
I-66	1982	15.5 (one way)	11,260 peak hr. 31,720 daily

Source: Reference 5.
Note: Other busways such as concurrent flow lanes and contra flow lane are not shown in this table.

and ride or park and ride service , the transitway rapid service can be utilized between stations. The design of the transitway station, of course, has to take into account the requirements for such users. A second type of service made possible by the transitway is the direct express service that provides the pick-up/delivery as well as the rapid line haul components without the need for transfer buses. The line haul vehicle provides the local feeder service.

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Legend
 --
|S |  Station            ----  Transitway and rapid
 --                      ----  transit service between
                                stations
...  Direct express via transitway
+++  Local feeder
~~~  Transit service using transitway for part of
     the route
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Figure 1: Transitway Services

A third type of service is the general urban area-wide transit service that uses the transitway for a part of the overall route and thus enhances not only its average overall speed, but also the frequency of services between some stations on the transitway. For this service, entrance/exit ramps would be required. Finally, there is the opportunity to develop feeder service that provide access to stations.

The LRT System

A light rail transit-based system operating on surface routes provides the line haul service between stations. Feeder services are provided mainly by buses. Types of services that can be provided by an LRT system are shown in Figure 2. These are noted below:

- The rapid transit service between stations, serving the walk-in, park and ride and kiss and ride type of users,
- The connecting trips that use feeder buses for a part of their journey or connecting trips that require intermodal transfer.

An LRT system provides a rapid service along its route. Access to its stations could be on foot, kiss and ride, park and ride and transfer from a bus (intermodal) service. As compared to bus rapid transit, a higher percentage of passengers transfer from another vehicle. In the case of Edmonton's LRT system, about 90% of the riders at the residential end start or finish their trip on a feeder bus (7).

TRANSITWAY AND LRT: CAPACITY AND LEVEL OF SERVICE COMPARISONS

Capacity of a rapid transit line or a corridor can be defined in terms of seats per hour and also passengers per hour.

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Legend:

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 --
|S | Station                      ---- Rapid transit service
 --                               ---- between stations
+++ Local feeder
*** Bus transit intermodal
    transfer
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Figure 2: Light Rail Transit Service

As an indicator of maximum passengers that can be served safely during an hour under prevailing conditions, this measure reflects the dimensions and performance of vehicles in terms of maximum speed, acceleration/deceleration, braking rate, maximum grade, geometrics, number of seats, crush load, design load, number of units in the train and number of trains per hour. Also, operating method of vehicle has an effect (e.g., manual vs automated) (8). Additionally, the design of stations effects line capacity (e.g., ability to pass loading vehicles).

Level of service indicators of rapid transit service include the overall average travel speed (including station stops), frequency of service, access to station, number of transfers, the quality of ride, and availability of seat.

Level of service and capacity estimates have been reported by the World Bank on a generic basis (Table 2) (9). Line capacity estimates that have been developed by studies conducted for Ottawa-Carleton and Calgary are shown in Table 3.

Table 2
Transit System Capacity and Level of Service

System Characteristics	Bus in Mixed Traffic	Bus Only Lanes	Transitways	LRT Surface Exclusive
Vehicles per Train	-	-	-	3 to 6
Lane/track Capacity: Pass./hr.	10,000-15,000	15,000-20,000	30,000	20,000-36,000
Average Overall Speed: km/hr	10-12	15-18	15-30	15-25

Source: Reference 9.

Table 3 Line Capacity of Transitway and LRT

	Transitway		LRT	
	Seats/hr	Pass./hr	Seats/hr	Pass./hr
Ottawa-Carleton Studies	12,500	16,000	11,500	19,200
Calgary Transit Department				14,400-24,000

Source: References 8 and 10.

Lane/track capacity estimates shown in Table 2 are the maximum number of passengers that can be carried on a single lane or track past a point during one hour. Here, most favourable conditions are assumed in the estimation of throughput of a unit of transit capacity. Journey speed shown is the average overall speed taking into account loading and unloading time at stops and stations. Average overall speeds in mixed traffic may be substantially less in congested areas (9).

Transitway technology offers the opportunity to use large capacity 60 feet articulated buses for increased capacity and efficiency. However, the use of large capacity buses does not reduce the very high frequency of bus service. The use of large articulated buses, and maintaining safe headways results in a practical capacity of 16,000 or more persons per hour per direction. With off line stations and terminals equipped with multiple boarding platforms, volumes much higher than 16,000 (e.g., 30,000) passengers/hour/lane, and journey speeds between 15-30 km/hour, may be attainable.

Light rail technology offers good quality service on fixed routes, serving stations en route. The control technology enables headways to be as small as 150 seconds. Maximum practical capacity of the LRT (with standees and 5 car trains) could be 24,000 or more passengers/hour/direction (10). LRT routes that can support 5 or 6-car trains operating on segregated tracks with grade separated intersections can experience peak capacity of up to 36,000 passengers/hour/track at journey speed of 25 km/h (9).

Information systems for bus transit and LRT technologies play a role in enhancing the quality of service. To date, much innovation has taken place in computer communication technology applications in bus transit. In the case of Ottawa-Carleton, in addition to an automated passenger information system, computer assisted radio communication systems for all buses, automatic vehicle location and control systems are expected to become operational by 1990s. On the other hand, information systems for the LRT need not be as sophisticated as those for bus transit due to the "tracked" nature of this technology and the relatively simple route structure.

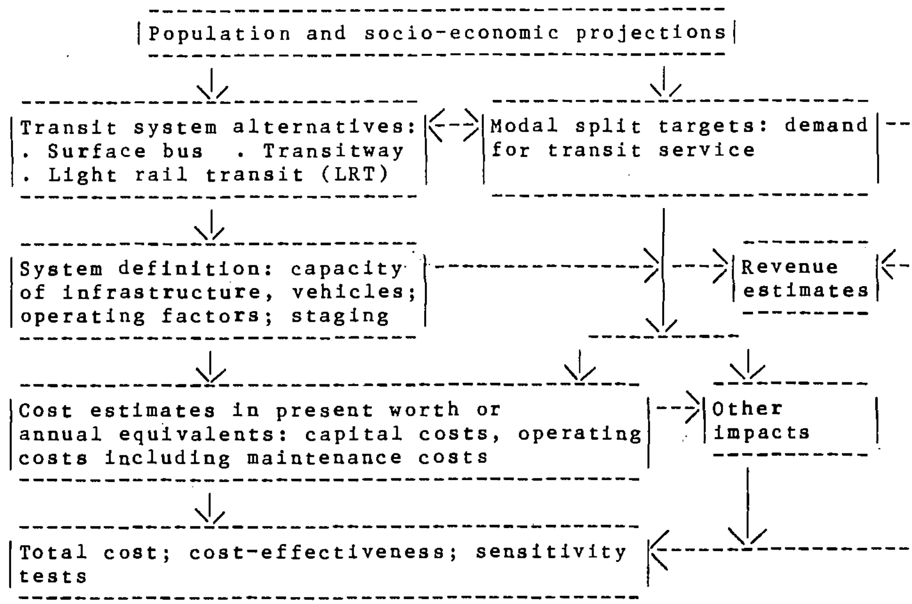

Figure 3: Methodological Framework for Economic and Service Assessment

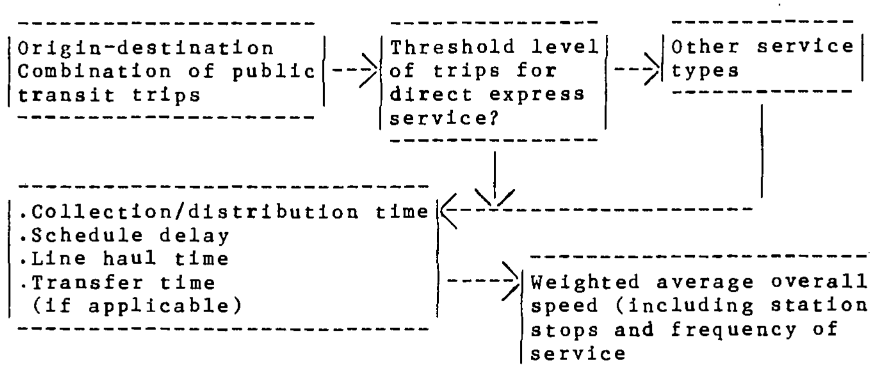

Figure 4: Level of Service Simulation: Transitway Case

COST-EFFECTIVENESS COMPARISONS

Cost-effectiveness comparisons require that for various system options, cost as well as selected effectiveness estimates are to be developed. Figure 3 presents the methodology for assessing the cost-effectiveness of public transit systems. Figure 4 presents an illustration of the technique for simulation of level of service. In this section, theoretical as well as actual cost and effectiveness figures are presented.

Theoretical Considerations

For given contexts, life cycle cost comparisons have to be made in order to establish the relative cost efficiencies of the various rapid transit technologies. Conceptually, the cost per passenger or passenger-km profiles for a range of volumes would suggest that for very low volumes, the surface bus is the cheapest mode. For higher volumes, the bus rapid transit is the cheapest mode and the LRT option would fit between the bus rapid transit and the intermediate capacity (grade separated) advanced light rail technology. The heavy rapid transit system would be the most cost efficient for very high volumes of passenger demand (Figure 5).

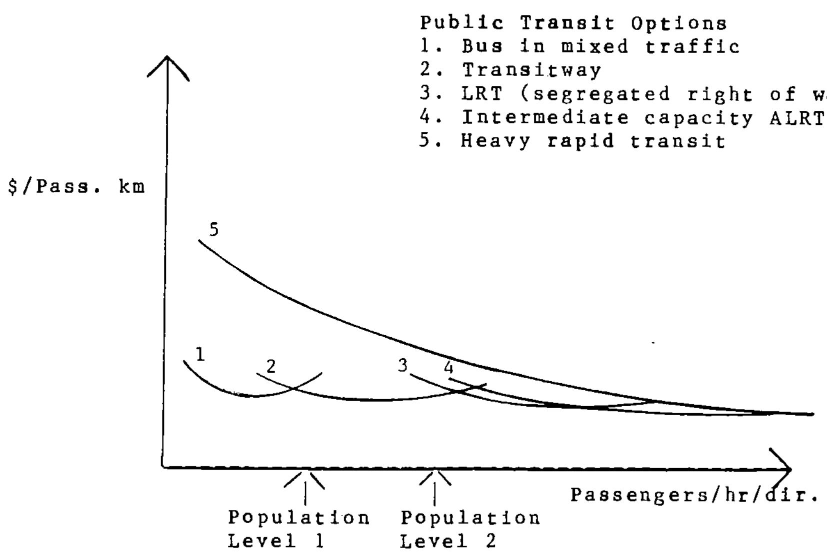

Figure 5: Conceptual Representation of Public Transit Cost-Efficiency

For a range of volumes, such as those encountered in low to medium density corridors, the transitway technology offers the least cost option on a life cycle basis.

The capital (facilities and vehicles) cost of the LRT system are higher than a bus rapid transit system. The two track LRT system with associated control technologies is costlier than busway. The station cost for the LRT could be higher as well depending upon the requirements for parking etc. In general, transitway stations, owing to bus feeder subsystem, require relatively low capital cost suburban stations as compared to LRT stations which have to accommodate higher parking needs. On the other hand, transitway stations have the additional feature of enabling a bus to by pass a loading vehicle, and exhaust systems are to be provided in the below grade stations.

Cost Comparisons

A number of urban areas have examined the relative cost of transit technologies. While cost comparisons reflect the local conditions such as availability of right of way, possibility of using existing railway tracks for the rail based transit system, design and operational features of raid transit options (e.g., use of standard buses vs. articulated higher capacity buses). In most instances, transitways have been viewed to require less capital cost for infrastructure and equipment. As for operating costs, much depends upon the assumptions made about system operations. In general, for higher volumes, the LRT option is noted to be operationally more economical than standard bus option due to the use of longer trains. On the other hand, the use of higher capacity articulated buses and innovative operational features such as interlining results in cost savings for the transitway option.

A 1969 study of relative costs of bus and rail transit system by Deen and James concluded that busways can be operated in a variety of ways and the efficiency of any given system option would depend upon the operating environment. In general, subway construction for an LRT type of system costs less than for bus. The use of articulated buses with 40% more seats than the conventional bus can result in cost reductions of 10-12% in total capital and operating costs in some instances. For transitways where no subways are required on a line, the use of articulated buses would enable volumes as high as 12,000 passengers per hour per direction to be served as cheaply as rail (2). For low volumes (i.e., about 4,000 passengers/hour/lane), articulated as well as standard buses could result in cost savings of 15-20% for service comparable to the LRT. For volumes above 12,000 (peak hour), rail systems become cheaper on a per passenger basis. Increasing interest rates would effect capital intensive rail system and increasing wage rates would impact the transitways somewhat (2).

Cost comparisons of alternatives reported in the technical studies carried out for Calgary and the Ottawa-Carleton are discussed here for illustration purposes (Tables 4 and 5).

Table 4
Cost Comparisons: Calgary (1987 Dollars in Million)

	Busways (Standard Bus)	LRT (6 Axle Articulated)
Annual capital cost	17,235	22,688
Annual operating cost	7,358	4,161
Total annual cost	24,593	26,849

Source: Reference 11.

The busway cost estimates (for Calgary) were developed for 4,200 persons per hour per direction and were based on standard 52-passenger buses. The busway and LRT costs were judged to be "similar" and it was believed that the cost advantage of the busways is eliminated due to increasing ridership (11).

As a part of planning studies for Ottawa-Carleton Region, four alternatives were costed under two population level scenarios. These are shown in Table 5. Also, Figure 5 illustrates this concept. Clearly, the transitway technology is the least cost option. Also, as population level increases, the operating cost difference between the articulated bus (with transitway) option and the LRT/articulated bus option decreases.

Table 5
Cost Comparison of Alternatives, Ottawa-Carleton Region (1987$M)

	Standard Bus	Articulated Bus	LRT/ St.Bus	LRT/ Art. Bus
		625,000 Population Level		
Annual Capital Cost	36.15	37.10	54.85	55.76
Annual Operating Cost	102.07	90.95	99.81	91.76
Total Annual Cost	138.22	128.05	154.66	147.52
		750,000 Population Level		
Annual Capital Cost	83.96	42.49	63.03	64.16
Annual Operating Cost	114.96	99.44	110.61	99.63
Total Annual Cost	198.92	141.93	173.64	163.79

Reference 12.

A comparison of alternatives shown in Table 5 suggests that the transitway option that utilizes articulated buses is the least cost solution (for the Ottawa-Carleton Region) for both the 625,000 and 750,000 population levels. Capital costs for the transitway are lower than those of the LRT. A comparison of Alternative 2 (Transitway) with the Alternative 4 (LRT and articulated bus combination) suggests that the differences in the operating costs narrows as population (and therefore ridership) increases (12).

Considering that in recent years, a number of rapid transit systems have been implemented, actual cost data have become available. A comparison of such costs is made here. Table 6 shows cost per kilometre per daily passenger. Also, in Table 7, other cost figures are compared. The various cost data presented here suggest that for low to medium density corridors, an LRT system would cost about 50% more to implement than a comparable system based on bus transitways and that annual operating costs would be higher than a bus transit based system. The operating costs for the LRT option on a unit cost basis drop considerably for the higher volume levels.

Table 6
Cost-Efficiency of Selected New Transit Systems in North America

Facility/ City	Year Opened	Cost/Km/Daily Passenger (1985 Canadian Dollars)
Ottawa-Carleton Transitway	1984	$160
Vancouver Advanced Light Rail System	1986	505
San Diego LRT	1981	510
Calgary LRT	1981	540
Portland LRT	1986	810
Edmonton LRT	1979	1460
Buffalo LRT	1985	1550

Source: Reference 13 (Based on B.C. Transit information).

Cost-Effectiveness Comparisons

Available cost and effectiveness estimates are used to develop a mapping of cost against average overall speed for a number of public transit options for low to medium density urban areas (Figure 6). These suggest that the segregated busways (transitways) are the most cost-effective option in providing a relatively rapid public transit service. Cost as well as speed estimates are expressed as ranges due to much variation in the actual implementation contexts.

A more comprehensive cost-effectiveness analysis is made possible by the data presented in Table 8. In this case the criteria are ranked and then converted into weights. All effectiveness criteria achievement levels are transformed into relative values and then weighted by the importance of criteria. The subjective estimates of effectiveness were mapped into a relative value scale of 0 to 1. The end result of cost against effectiveness can be seen in Figure 7. Once again, the transitway option is the most cost-effectiveness option.

Table 7

Cost Comparisons of Various Light and Intermediate Rapid Transit Systems in Canada

City/Facility	Length of line	No. of stations	Ridership Pk/hr/pk/dir	Ridership Daily	Cost*
Ottawa-Carleton West/Southwest Transitway	8.4 km	5	9,000	65,000	$88M ($11M/km)
Scarborough:LRT	7.0 km	5	2,100	18,000	196M (28M/km)
Edmonton:LRT	10.3 km	8	3,400	23,000	270M (26M/km)
Calgary:LRT South Line	12.5 km	14	4,500	32,000	210M (17M/km)
Vancouver: Advanced Light Rail**	21.0 km	15	7,000	78,000	854M (39M/km)

* Costs include property and dedicated vehicles (13).
** All data are actual except Vancouver (which opened in 1986).

IMPLEMENTATION CONSIDERATIONS

Bus rapid transit systems offer the opportunity to tailor service to demand. Also, as in the case of Ottawa-Carleton, the system can be developed gradually and the outside parts can be built first. The use of surface streets for bus transit permits such a strategy to be practical. In the case of LRT, a corridor has to be developed at once (2).

Other considerations could play a role in transitway vs. LRT decision in any particular region. There are a number of relevant issues that have to be considered, including the acceptability of

Table 8
Cost-Effectiveness Data

Cost/Effectiveness Data	Bus in Mixed Traffic	Buses in Reserved Lanes	Transitway	LRT Surface
Cost/pass.km (US $ 1985)	0.035	0.035	0.065	0.125
Effectiveness Measure and Rank:				
1. Safety	Average	Average	Good	Good
2. Avg. overall speed Km/hour	11.0	16.5	22.5	20
3. Noise	Average	Average	Good	Average
4. Visual intrusion	Good	Good	Good	Average
5. Desirable land use impact	Poor	Average	Good	Good
6. Air pollution	Poor	Average	Good	V. Good

Note: All items except land use impacts are based on World Bank data (Reference 9). Ranks assigned are for illustration purposes.

the use of line haul buses on neighbourhood streets, the treatment of central business district segments of the rapid transit network in terms of integration with the urban setting and environmental compatibility of bus transportation with the activities of the urban centre.

Bus rapid transit systems at present cannot be considered risky since there is ample experience with their use on exclusive right-of-way such as Ottawa and Pittsburgh. The flexibility in staging is also a feature that should reduce risk. As for bad weather, with appropriate support, transitways need not encounter problems. Safety has been viewed as another feature in comparing transitways and LRT technology. While the control system for the LRT is automated, the human control of buses is not expected to create hazardous situations under low headway conditions.

CONCLUSIONS

Transitways are a relatively new option to the conventional rail based systems for low to medium density urban areas. For volumes of up to 16,000 persons per hour per direction and even somewhat higher volumes, transitways using high capacity articulated buses provide a cost-efficient rapid transit service, perhaps even cheaper than the LRT option under normal circumstances. The transitway is less capital intensive and for a range of volume levels, it offers comparable or less operating costs. As for level of service, the central business district

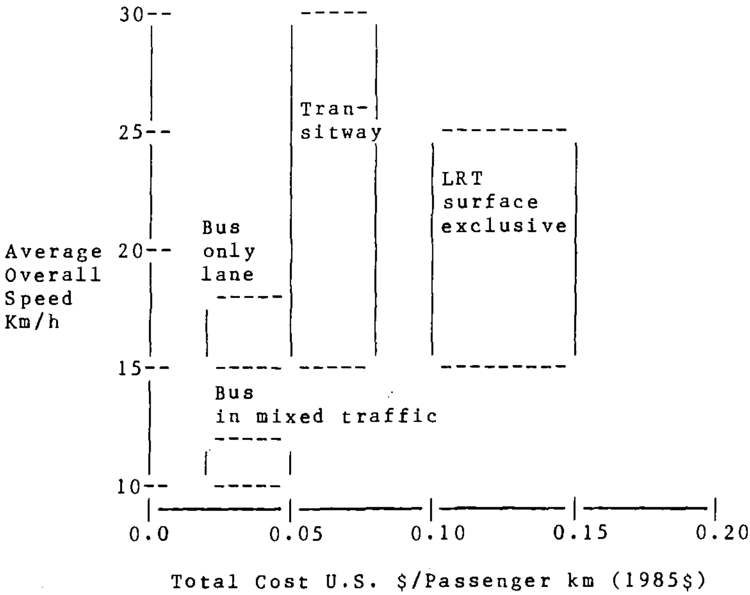

Figure 6: Cost vs. Average Overall Speed
Source: World Bank Data

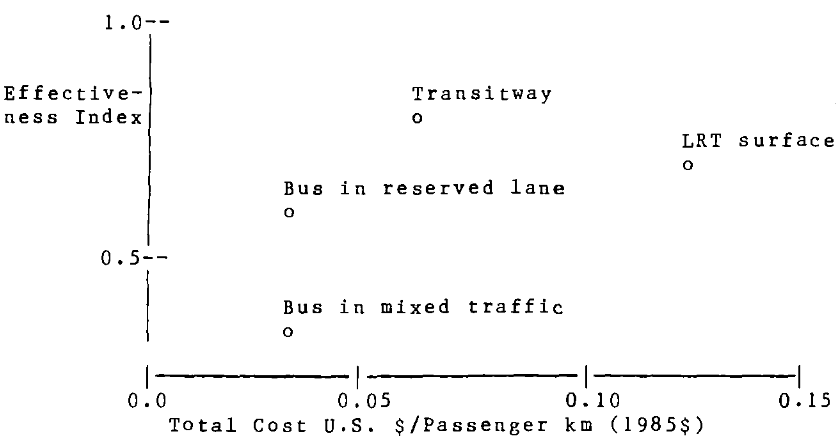

Figure 7: Cost-Effectiveness of Public Transit Alternatives

oriented users can expect comparable or somewhat better service (due to less transfer) than the LRT. The transitway system is better suited to serving dispersed activity centres and non-central business district travel needs. Transitways offer the flexibility of developing rapid transit system incrementally whereas a rail based system has to be built at once.

It is contended that in developed as well as developing countries where it is possible to designate roadways for the exclusive use of buses, there is much merit in considering bus transitways as a serious option for low to medium density corridors. For the very long run, such facilities could be converted into intermediate capacity rail rapid transit system. For a considerable time period (even as long as 20 years), the development and use of transitways vis-a-vis LRT technology under favourable conditions yield cost savings to an urban area.

ACKNOWLEDGEMENTS

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