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Comparison of Light Rail Transit With Bus Semirapid Transit

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Abstract

Selection of transit modes is one of the most important decisions in the transit planning process. A particularly important decision is the selection between bus and rail modes, because it influences the type of service that will be offered and, more importantly, the role transit will play in the city. Ultimately, such a decision has an impact on the quality of life in the city. It is therefore necessary to include in the selection process the physical and economic characteristics of modes, as well as the quality of service, attraction of passengers and the impacts of the transit system on its served area and the entire city or suburb.

Disciplines

Civil Engineering | Engineering | Systems Engineering | Transportation Engineering

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COMPARISON OF LIGHT RAIL TRANSIT WITH BUS SEMIRAPID TRANSIT

Selection of transit modes is one of the most important decisions in the transit planning process. A particularly important decision is the selection between bus and rail modes, because it influences the type of service that will be offered and, more importantly, the role transit will play in the city. Ultimately, such a decision has an impact on the quality of life in the city. It is therefore necessary to include in the selection process the physical and economic characteristics of modes, as well as the quality of service, attraction of passengers and the impacts of the transit system on its served area and the entire city or suburb.

1. Purpose and Scope of This Paper

The purpose of this paper is to present a comparison of the Bus Semirapid Transit – BST (bus services on separated lanes, with distinct stations, large buses and good information), and Light Rail Transit – LRT - modes. The consequences of the massive replacement of tramways by buses several decades ago will be briefly reviewed, particularly the impact of this conversion on the quality of transit systems and their role in cities. The reasons for the rapid development of the LRT and BST modes since the 1970s are then discussed. It is pointed out that the differences between the two modes are not only in technology, but also in the type of service, its image and impacts.

A brief, but systematic comparative analysis of the LRT and BST modes is then presented to show their relative advantages and disadvantages. This analysis is used to define the optimal domains of each one, LRT and BST, to evaluate their likely future roles. The main goal of this analysis is to improve the understanding of the characteristics of rail and bus modes and assist rational decision-making, thus reducing the impacts of various lobbies or narrow "minimum cost" and other naïve theoretical studies of mode comparisons.

2. Reasons and Consequences of Tramway Replacements by Buses

Major inventions and development of rail transit took place during the 1890's, and they resulted in the establishment of tramways and metros as nearly exclusive technology of urban transit. Bus and trolleybus vehicles became fully operational and practical only during the 1920's and 1930's.

Under the growing street congestion due to the increasing use of private cars during the 1930s and then again, even more seriously, during the 1950's, tramway services faced increasing delays and loss of passengers. Cities and transit agencies then adopted one of the two very different approaches to the required reorganization of their systems:

> **Upgrading Tramways Policy.** This policy of upgrading tramways was based on the goal to make transit attractive and competitive with the private car. The most important element to achieve this, was to place tramway tracks into separate rights-of-way (ROW) and give rail vehicles priorities at intersections. This separation made them largely independent of street congestion. Modernization of vehicles, operations, etc., followed.
>
> Cities pursuing the "Upgrading Policy," most typically those in Germany, Switzerland, Belgium and the Netherlands, led in the development of Light Rail Transit mode, which has been very successful in competing with the car travel and in attracting passengers. By creating reliable LRT service and its visible infrastructure, this policy has also had a major positive role in the efforts to create human-oriented, livable cities.
>
> **Tramway Replacement Policy.** Replacement of tramways by buses was done to achieve a different goal: adjust transit to the street conditions. Being more "flexible" than rail vehicles, it was expected that buses would operate better in congested streets.
>
> This "Replacement Policy", which is of particular relevance for this paper, was pursued not only in many cities, but also in entire countries, such as Great Britain, France and the United States. The main logic and arguments for this policy can be summarized as follows:
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> - Buses are more flexible than rail vehicles, so that they can progress faster in congested traffic;
> - Buses can stop at the curb, they do not require special stop areas;
> - Bus route alignments can be changed easily, temporarily or permanently;
> - Being smaller units, buses can offer higher service frequency;
> - With greater frequency, buses can serve more lines and require much less transferring;
> - Buses require much lower investment, particularly for the infrastructure.
>
> The arguments that tramways are more permanent, spacious and comfortable, have higher capacity and lower operating costs, etc., were generally swept aside by evoking the statement that they are "old-fashioned", and the future is with roads, not rail.

The consequences of the conversion were far-reaching for the entire transit systems and for cities. For lightly traveled lines, the conversion resulted in many benefits: better service, lower costs and possibility to expand services into low-density suburbs.

A major problem was, however, that there was a strong tendency to disperse transit into many overlapping bus routes with less frequent services and weak image. Thus a serious problem was created, that the entire transit system degraded from a very distinct set of frequent, visually strong, permanent rail lines, to a large set of lines with lower service frequency, less distinction, lower passenger attraction and virtually no ability to interact with urban form and land use development. Generally, the role of transit in the city was seriously weakened and reliance on cars, with all its negative consequences, kept increasing.

Experiences from many cities have clearly shown that the concept of “flexible transit” is in many ways counterproductive. Transit vehicles need to have separate ways, rather then be “flexible” in congested traffic; their routes should be permanent, rather than changeable; their stations must be distinct if they are to influence land uses and urban developments.

Consequently, the replacement of tramways by buses resulted in better economy and service improvements in smaller cities and on lightly traveled lines; but on major lines and in large cities, it represented a downgrading of transit and its image. This was obvious by the impact such changes had on the number of passengers. For example, in the United States there were massive conversions of streetcars (tramways) to buses during the period 1945-1965, so that buses were introduced to hundreds of new routes. Yet, during this entire period the total number of passengers on this rapidly increasing bus network declined every year.

Another proof of the decline of transit with the introduction of buses and “flexible”, i.e., extensive instead of intensive networks, can be seen even today by comparing the cities which pursued the “Upgrading Policy” vs. those which followed the “Flexible Transit Policy.” The role of transit and its accessibility to other than daily users, such as incidental users and visitors, is distinctly weaker in all-bus cities, such as Seattle, Detroit, Lima and Bangkok, than in those served by rail networks, such as K ln, Vienna, Melbourne and Hong Kong.

3. Increasing Need for Intermediate Systems: LRT and BST

The growing congestion on urban streets and highways during the 1950-1980 period led to the recognition of the vital role of transit for cities. However, it became clear that transit can play a significant role only if it offers high level of service, competitive with the private car; for this, transit must be separated from general traffic, i.e., it must have ROW category A or B. A result of this realization was a wave of metro systems construction in large cities around the world: their number increased from 20 in 1955 to over 100 today.

While the high investment in metros can be justified for high-capacity lines mostly in large cities, there is a great need for medium-capacity transit systems which utilize partially separated ROW, i.e., semirapid transit. With distinctly better performance than street transit (bus and tramway) modes, semirapid transit involves much lower investment than metro because of the lower cost, partially separated ROW, shorter and simpler stations and less restrictive alignment. It also offers possibility for gradual upgrading of lines.

The basic characteristics of the three basic mode categories – street, semirapid and rapid transit – are presented in Table 1. The main difference between them is the ROW category: street – C, partially separated (typically, curbed street medians) – B, and fully separated (tunnel, aerial) – A. Vehicle/train type, propulsion and control are logical results of ROW types: for street operations buses with internal combustion engines dominate, for rapid transit electric guided (rail) systems are used exclusively. In the semirapid transit category, highlighted in the table, the bus and rail modes overlap.

Mode Category \ Characteristic	ROW Category	Mode	Support & Guidance	Propulsion	Control	Cars per Transit Unit	TU Capacity (spaces)
Street transit	C	Bus	Road / Steered	ICE	Visual	1	80-125
	C	Tramway	Rail / Guided	Electric	Visual	1 - 3	100-300
Semirapid transit	**B**	**BST**	**Road / Steered**	**ICE**	**Visual**	**1**	**80-180**
	B	**LRT**	**Rail / Guided**	**Electric**	**Visual / Signals**	**1 - 4**	**100-720**
Rapid transit	A	LRRT	Rail	Electric	Signals	1 - 4	100-300
	A	Metro	Rail	Electric	Signals	4 - 10	720-2500
	A	Regional Rail	Rail	El. / Diesel	Signals	3 - 10	540-1800

List of abbreviations

ROW Right-of-Way
ICE Internal Combustion Engine
BST Bus Semirapid Transit
LRT Light Rail Transit
LRRT Light Rail Rapid Transit

LRT Development. The cities which had followed the "Transit Upgrading Policy", have been in excellent position to obtain semirapid transit systems – they developed LRT systems gradually, as their consistent policy goal of creating high-quality transit. The cities which had followed the "Flexible Transit Policy" faced a huge gap between their street transit (buses on streets) and metros. In many of them the need for semirapid transit led to the construction of new LRT systems. In the United States alone, more than 20 cities have built new LRT lines since 1980; France, Britain, Spain, Italy and other countries joined, although Japan, Korea and South American countries have been lagging in this development, largely because of inadequate understanding of the characteristics, capabilities and potential role of LRT in the cities. Overall, however, it can be said that the development of LRT systems in the last 25 years can be described as remarkable.

LRT has been developed in many different forms. It has a great diversity of ROW types, from tunnels and railway lines to pedestrian streets; stations are simple at street level, as well as separate structures with high platforms; cars are conventional and low-floor, mostly articulated, from 14 to 40 meters long, operating as single units or trains of up to four cars. They play different roles, but most of the new systems have become backbones of transit in the served cities, such as San Diego, Calgary, Nantes and Manchester.

BST Development. Faced with the need to upgrade transit, some cities operating buses only focused on developing an upgraded bus system: Bus Semirapid Transit - BST, (also known as Bus Transit System - BTS or, recently, incorrectly designated as Bus

"Rapid" Transit – BRT). This development of BST has had many advancements, as well as some setbacks. Major ones are briefly described here.

- Exclusive bus lanes and busways were built in a number of cities. The best known, successful ones are in Sao Paulo, Ottawa, Curitiba, Adelaide and some European cities.

- When the concept of High-Occupancy Vehicle (HOV) lanes or roads was introduced in the United States, it led to the conversion of busways to HOV facilities. This represented a degradation or disappearance of exclusive bus facilities: allowing all vehicles with 2, 3 or more persons to mix with buses reduced reliability and eliminated distinction of bus services, while it improved travel of their main competitors, vans and cars. In the United States busways have virtually disappeared, with the exception of Pittsburgh, where they are owned by the transit agency.

- Every few years there have been strong promotional campaigns for buses, claiming that "buses can do everything LRT does, but for much lower cost." One such campaign was launched when Daimler Benz developed the O-Bahn or Guided Bus in the early 1980's. Many cities considered the guided buses as an alternative, but only one major (Adelaide) and several small systems with this technology have been built. The other cities decided that the guided bus in most cases is inferior by performance, service quality and environmental impacts to LRT on one side, while it is less operationally efficient than the conventional busway on the other.

- Many busways have been developed as *commuter transit* facilities, which operate unidirectionally during peak hours only. They are very efficient for commuters, but they do not represent regular, all-day transit systems. Typical examples are the bus systems in Houston, Washington-Shirley and Seattle.

- Vehicle technology has had major advances. Improved articulated and 12-m double-decker buses were followed by double-articulated and low-floor buses. The former are used in special cases only (long lines with few turns), while the latter have become standard vehicles in many European countries. Improved engines for reduced pollution are being successfully introduced in the United States and many other countries.

- Bus lanes have faced a similar problem to busways: pressure to let other vehicles, such as taxis, HOVs, trucks, etc. The pressure to invade a lane which is less congested is very strong. In recent years in the United States even HOV facilities are under attack by the motorists who see uncongested lanes next to the congested lanes they are on.

- The successful bus facilities are found in the cities which have very strong planning, such as Ottawa, Curitiba and Sao Paulo. Some small cities, such as

J nk ping in Sweden, have shown that semirapid transit can be developed by buses at a scale which neither can justify investment in rail, nor they need it for a small or moderate size system. In these cities bus lanes are strictly reserved for buses only, and the type of service has many elements typical for rail systems.

- Deregulation of bus transit, such as in Great Britain, has resulted in disintegration of bus services and made their technical and organizational upgrading much more difficult. For example, a very effective busway in Lima, Peru was discontinued when deregulation was introduced.

A serious problem in improving bus services has been that the service misconceptions adopted largely when buses were introduced on entire networks still persist with many bus systems: they have "flexible" operations with many overlapping lines and frequent stops, representing complex networks with weak visibility.

4. Analytical Comparison of LRT and BST

Both LRT and BST represent semirapid transit category of modes, but they differ in many characteristics. Table 2 presents a review of characteristics of these two modes classified into three groups: system components, lines/operational elements and system characteristics. Each one will be briefly discussed. It should be borne in mind that these are general characteristics, not necessarily true for each specific transit system.

Mode / Characteristic	**Bus Semirapid Transit (BST)**	**Light Rail Transit (LRT)**
System Components		
ROW	B (C)	B (C, A)
Support	Road	Rail
Guidance	Steered	Guided
Propulsion	ICE	Electric
TU control	Visual	Visual / Signal
Vehicle capacity [spaces]	80-180	100 - 250
Max TU size	Single vehicle	1 - 4 car trains
TU capacity [spaces]	180	4x180 = 720
Lines / Operational Elements		
Lines	Many	Few
Headways on each line	Medium / Long	Short
Stop spacings [meters]	100 - 300	250 - 500
Transfers	Few	Many
System Characteristics		
Investment costs	High	Very High
Operating costs	Medium	Low
System image	Good	Very Strong
Impacts on land use and city livability	Weak	Strong
Passenger attraction	Good	Excellent

Legend: ROW Right of Way
TU Transit Unit
ICE Internal combusion engine

The fundamental differences between system components of bus and rail modes are illustrated graphically in Figure 1. This diagram can show any mode of urban transportation, be it trolleybus, bus, metro or automated people mover, by a line connecting respective components of that mode. The diagram shows first the most important component - ROW category, followed by the components of technology and operation. On the left are the base-level types of the components: single road vehicles steered and controlled by the driver. On the right are advanced modes: guided, with electric propulsion, signal control and automated driving.

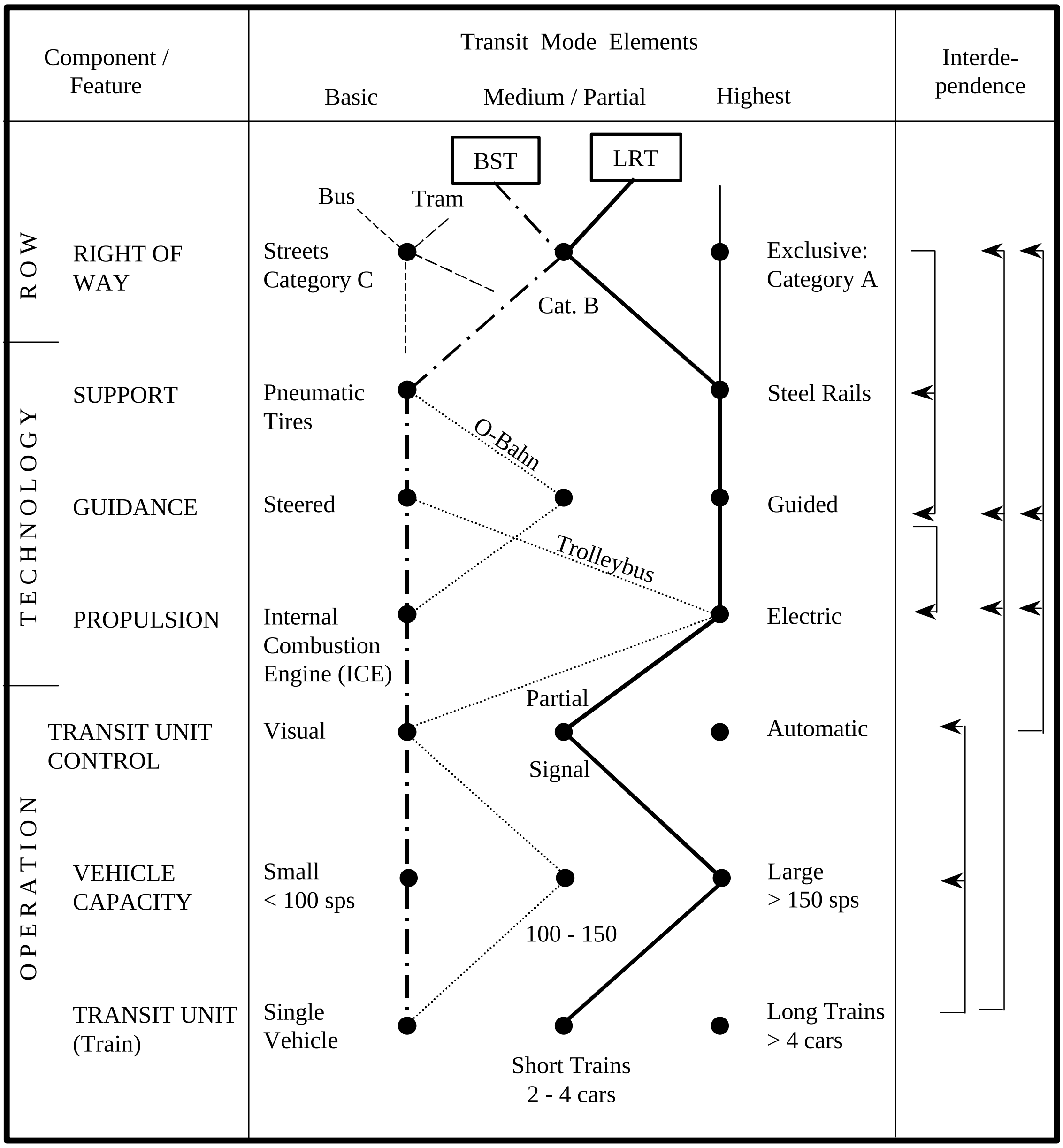

Figure 1 Graphical representation of the differences between Bus Semirapid Transit and Light Rail Transit

The basic transit system, bus-on-street, which is most economical and efficient for low-volume lines, has the elements on the left side of the diagram; the highest-performance transit mode, metro with automation, would be represented by a line on the right side. The lines representing BST and LRT clearly show that the two modes have generally the same ROW category, but by all other components LRT has a higher-performance technology: guidance which makes possible use of larger vehicles and operation of trains, electric propulsion and signal control, usually used only on high-speed or tunnel sections.

With respect to **elements of lines and operations** presented in Table 2, typical BST lines are more extensive, LRT lines more intensive. Bus lines and their networks have more stops and lower speed, and usually longer headways than rail lines. Fitted primarily to the needs of regular users on certain individual lines, BST lines are less integrated and convenient for transferring among lines. When an LRT line is built, the network is changed from extensive to intensive one, with trunk and feeders. This is shown on the example of Sacramento, California, in Figure 2.

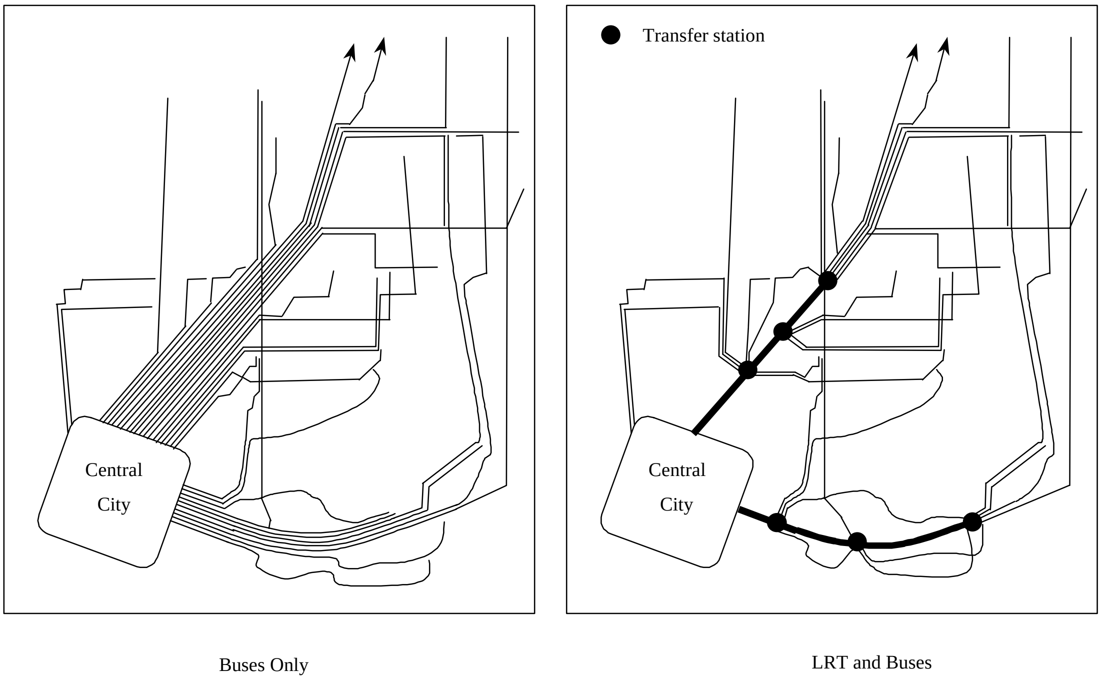

Figure 2 Change from an extensive bus network to an intensive, more efficient and attractive LRT-Bus network

It should be noted that bus lines do not have to have the form of extensive but uncoordinated networks. Actually, it can be said that, generally, the more operational features typical for rail lines the buses have, the more passengers they attract. This is clear from the fact that the most successful BST systems, such as Ottawa, Curitiba and the planned "BRT" systems in several U.S. cities, are created by changing them from extensive networks with many lines and close stops to major trunk lines with ROW category B, large (articulated) vehicles, longer station spacings and transfers to feeder bus lines.

The system characteristics, given in the third section of Table 2, are a result of the preceding system components and line elements. The physical characteristics of the two modes are inherent and they can not be changed: LRT is a higher performance, stronger image mode than BST, and it is generally superior for serving major transit corridors. Bus technology requires lower investment and it is easier to implement; therefore, where high capacity and high comfort are not needed, BST is the superior mode. Thus, LRT generally dominates the higher range of the semirapid transit applications, BST is superior in its lower range.

Which one of the two modes is selected for a specific case in the "middle range," depends not only on the passenger volumes, types of lines and estimated costs, but also on the last three items in the table: system image, impacts and passenger attraction. These aspects are difficult to quantify, but they may have a great significance for mode selection in many cases, because they influence the role of transit and thus the character of the city.

Evaluation of these aspects depends greatly on local attitudes: in some cases transit service is considered with respect to its transportation function only; in others, the visual and symbolic aspects of rail transit, its sense of permanence and mutual interaction with urban activities and development are also considered very important. Actually, in some cases the attractiveness and symbolism of LRT is considered more important than its transportation function. This is quite obvious in the cases where classical tramway lines are build for functions which could easily and more cheaply be performed by buses. Or, old trolleys are sometimes used on sections of modern LRT networks, such as in San Jose, San Francisco and many other cities.

In recent decades many efforts have been made to develop and, in some countries, legally require application of a systematic, rational planning process and comparison of modes. However, experience has been that in city after city the minimum cost can not be the only, sometimes not even the dominant criterion, for two important reasons: LRT and BST offer different quality of service, attract different numbers of passengers and have different impacts on the surroundings and on the city. The two modes therefore represent different "packages" of cost, service, ridership and impact on the city. Two examples illustrate different impacts of these "packages" on mode choice.

- Long lines with heavy passenger volume will favor LRT and its advantages will outweigh the complexity of transfers to other lines; short trunk lines with a great number of branches favor buses, because transfers are inconvenient for short trips.

- If minimum investment is an important factor and labor costs are low, BST will have an advantage; on the other hand, in the cities which want to improve their livability, develop pedestrian zones and encourage use of transit, LRT with its strong image, interaction with urban development and compatibility with pedestrians in urban centers will have a distinct advantage over buses.

5. Conclusions and Likely Future Roles of LRT and BST

The need for semirapid transit, competitive with the car, will increase further in the future. LRT is and will remain the dominant mode in this category of transit systems. This mode has proven to be adaptable to many different conditions, it can offer a variety of performance types and levels at different cost ranges. At the upper end of performance are the systems utilizing mostly aerial and tunnel alignments, such as Stuttgart, Buffalo and St. Louis; at the "functional" end are the systems using a diversity of low-cost alignments, such as Nantes, San Diego and Calgary. Probably the most cost-effective system is in Konya, Turkey, which built tracks in street medians and purchased second-hand LRT double-articulated vehicles in excellent condition from Germany. Weekday ridership is about 120,000 and growing. This may be an excellent model for many cities in developing countries.

The main limitation for LRT is the considerable organizational and funding effort that its introduction requires and inadequate understanding of this mode and its potential, which is still found in many cities of Korea, Japan, Brazil and other Latin American countries.

In addition to the main lines in medium- and large cities, LRT is likely to be increasingly used in suburban areas of large as well as mega-cities, such as New York, London and Paris. Moreover, the thinking existed in 1960, that in medium and large cities which are building metros, LRT will be eliminated. This has been proven wrong. In many cities, like Munich, Berlin, Milan, Prague and Budapest, modernized LRT systems complement metro networks and continue to play a very important role.

The need and opportunities for applications of BST are also bright, because there is an increasing understanding that major bus lines must be upgraded from "flexible" services in mixed traffic, to the lines with physically separated lanes, large vehicles, coordinated transfers to feeder lines and distinct information. There are many cities that need such services and can provide them by buses at a lower cost and with a smaller organizational and financial effort than LRT would require. In such cases the stronger image of rail does not justify introduction of a new technology, and BST is the superior choice.

Although technologically considerably simpler than rail system, BST still needs a major organizational effort, particularly because the rudimentary feeling of the general public, that streets are open to all vehicles, must be overcome. In many cities BST will continue to face pressures from car users and highway lobbies to "utilize unused capacity of busways by other vehicles." Another obstacle to BST systems is the privatization and, particularly, deregulation of buses, which practically disintegrates the system and makes coordinated efforts extremely difficult.

A rational professional analysis of the relationship of LRT and BST should contribute to the understanding that these two modes have somewhat different, often complementary, rather than competing roles in cities. It should suppress excessive advocacies for each one of these modes. The fact must be borne in mind, that the main objective of transportation planning is how to upgrade transit to high-quality, attractive systems. The mode which can best meet this requirement and be efficiently coordinated with urban plans for creating an attractive, livable city, is the one that should be chosen.

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1

Typical LRT median ROW: distinctly separated from roadway (Frankfurt)

2

Bus lane: low investment cost and simple, but difficult to protect for buses only (Berlin)

3

Separate busway with 2+2 lanes in stations for overtaking (Ottawa)

4

Fence in station prevents pedestrians from crossing the roadways (Ottawa)

5

LRT in shopping street in Karlsruhe mixes with pedestrians; the same vehicles proceed to railway tracks and serve distant suburbs

6

New LRT system in Strasbourg has triggered pedestrianization of a large center city complex

7

Hundreds of buses and trolleybuses per hour use this busway in Sao Paulo

8

Busway entering an elaborate, long multilane station in Sao Paulo

9

In city centers with congested streets, LRT typically uses tunnels (Frankfurt)

10

LRT integrated with office building in San Diego