averaged over short time periods. In addition, the high degree of variability and randomness suggests that caution should be exercised in interpreting maximum load data; statistical analyses of such data are unlikely to alert planners to problems and changed conditions they would otherwise miss, but they are likely to cast doubt on the reality of apparent problems and changes. The variability of the data also implies that it will always be impractical to achieve close matches between seating capacity and demand, because considerable overcapacity must be provided to prevent serious overcrowding. For instance, if all scheduled one-way trips are considered, no route in either San Diego data set had more than 74 percent of its seats occupied at its maximum load point, despite several cases of fairly serious overloading.

When viewed from the standpoint of the system as a whole, the causes of variations in maximum loads appear to be quite complex. Variations in ridership are obviously the most important influence, but there are also wide variations, both for individual routes and between routes, in spatial peaking patterns and time-of-day trends in total ridership and the fraction of passengers on board at the maximum load point. Although some of the reasons for these variations are fairly obvious (for instance, the marked differences between express routes and most local routes), much of this variation remains unexplained.

ACKNOWLEDGMENT

The data used in this study were furnished by the staff of the San Diego Transit Corporation. The author would particularly like to thank Richard Murphy and Janet Braaten of the SDTC for their assistance in providing access to the data and in discussing some of the results.

REFERENCES

1. N.H.M. Wilson and S.L. Gonzalez. Methods for Service Design. In Transportation Research Record 862, TRB, National Research Council, Washington, D.C., 1982, pp. 1-9.
2. Bus Route and Schedule Planning Guidelines. NCHRP Synthesis of Highway Practice 69. TRB, National Research Council, Washington, D.C., 1983.
3. R.M. Shanteau. Estimating the Contribution of Various Factors to Variations in Bus Passenger Loads at a Point. In Transportation Research Record 798, TRB, National Research Council, Washington, D.C., 1981, pp. 8-11.

Publication of this paper sponsored by Committee on Bus Transit Systems.

O-Bahn: Description and Evaluation of a New Concept

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ABSTRACT

The O-Bahn system, developed in the Federal Republic of Germany in recent years, consists of conventional diesel buses equipped with a special guidance mechanism that can be extended or retracted. The vehicles thus can run on regular streets or on special guideways that have two simple vertical guidance surfaces. The O-Bahn concept is intended to combine the advantages of low-investment bus operation on streets in low-density areas with the advantages of narrower right-of-way and greater highway safety of guided-mode operation on higher density route sections. However, because the basic vehicle is the standard (or articulated) diesel bus, the most important advantages of guided modes--high-capacity vehicles, ability to form trains, electric traction with a number of superior aspects, and fail-safe running--are not captured. A systematic analysis of all characteristics shows that the O-Bahn is much more similar to semirapid bus (bus lines that use busways and other separated ways on individual sections) than to light rail transit (LRT). In comparison with semirapid bus, the O-Bahn offers the advantages of narrower right-of-way, somewhat greater comfort and safety, guaranteed permanent retention of the exclusive right-of-way for buses only, and greater suitability (O-Bahn with dual-traction vehicles) for operation in tunnels. These advantages must be weighed against the higher investment cost and lower capacity and operating flexibility of the O-Bahn, which is due to the inability of O-Bahn vehicles to overtake or bypass each other on the guideway. O-Bahn represents a higher cost, higher quality system than semirapid bus, which may be advantageous for use in such special cases as areas with narrow rights-of-way. It is not suited for lines that require high-capacity, low-cost transit systems, which are typical of cities in developing countries.

Attempts to develop a transit system that can operate in steered and guided modes are not new. During the 1920s and 1960s there were several attempts to develop railbus--a bus that could also operate on standard rail track. Because of major mechanical problems and basic structural differences between highway and rail vehicles, these attempts were not successful and they were abandoned.

The Barrett Corporation (USA) demonstrated in the early 1960s that a specially equipped bus can be electronically guided quite precisely by an underground cable. That concept has recently been pursued and further improved by Maschinenfabrik Augsburg-Neurnberg (M.A.N.) Corporation in the Federal Republic of Germany under the sponsorship of the BMFT (German Ministry for Research and Technology).

By far the most successful development of a bus that can also travel in guided mode has been the O-Bahn system, developed recently by Daimler Benz AG, also under sponsorship of the BMFT. This system has been brought to the operational stage and has been in operation on test lines in Essen, Germany, since 1981; it is also being built as a complete new transit line in Adelaide, Australia. In addition to the basic guided bus, several other vehicle types and related components have been developed as possible complementary elements to improve some of the O-Bahn's features and make it a more diversified transit system. These include a dual-mode diesel bus-trolleybus; a four-axle, 24-m-long double-articulated bus for guideway operation only; an exhaust-collecting mechanism for tunnel operation of diesel buses; and several others.

A number of articles have been published about the O-Bahn (1-4). Most of them focus on its description and advantages; few evaluate it completely or compare it with other modes.

The purpose of this paper is to briefly describe the O-Bahn concept and its technical features, to evaluate its operational characteristics, and to compare it with similar conventional transit modes. This will lead to a conclusion about the potential of the O-Bahn for applications in cities and its place in the family of urban transit modes.

SYSTEM DESCRIPTION

Vehicle

The basic vehicle for the O-Bahn system is a regular diesel bus equipped with a retractable guidance mechanism. The mechanism consists of special arms with small horizontal solid rubber rollers that, when extended, lie in front of the front axle wheels, as shown in Figure 1.

When the O-Bahn vehicle operates on streets and highways, the guidance mechanism is retracted and there is no visible difference between it and a regular bus. Before entering a guideway, the driver extends the guidance mechanism and drives through a funnel-shaped entrance (Figure 2). The rollers come in contact with the guidance surfaces and take over the steering function while the driver continues to control vehicle speed.

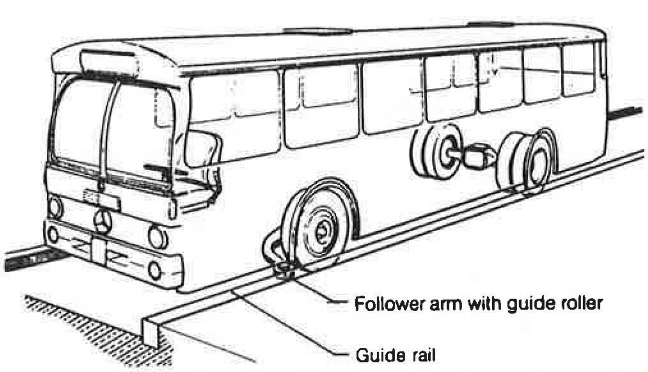

FIGURE 1 O-Bahn guidance mechanism *(1)*.

Infrastructure

The guideway consists of two horizontal concrete running surfaces for regular, running wheels and two small (25-cm-high) vertical surfaces on the outside of the running surfaces, at a distance (gauge) of 2.60 m (the bus is 2.50 m wide), against which the guiding rollers run, providing horizontal guidance (Figure 3). The guideway is supported by concrete cross beams, which are anchored to a series of 2.50-m-deep and 60-cm-wide bore concrete piles. This special foundation is necessary to ensure extremely precise horizontal and vertical alignment of the guideway because riding comfort is sensitive to the alignment.

Switching is done by alternate rising and lowering of the two mutually crossing guiding surfaces within the area of the switch.

Concept

The basic intent in the development of the O-Bahn system is to create a transit mode that will be capable of taking advantage of the benefits of operating on streets as well as those of guided technologies. In other words, the O-Bahn is intended to combine the lower investment and nearly unlimited mobility of the bus--its ability to operate on lines anywhere on the street and highway network--with such advantages of guided modes as narrower right-of-way, greater riding comfort and safety, and a stronger image. Its technology allows the O-Bahn to operate under either of the modes on any section of a transit line.

Thus the dual-mode feature of the O-Bahn could make this mode suitable for providing economical service in low-density suburban areas as a bus on streets (right-of-way category C) as well as for serving higher capacity lines converging toward a city center where, similar to light rail transit, it would use a separated guideway with street crossings at grade (right-of-way category B) or, if some sections allow it, even full separation (category A).

Characteristics of Dual-Mode Systems

All transport systems with dual-mode features (i.e., modes that can operate in two different ways) have the advantages of a broader range of applications or uses but also the disadvantages of greater complexity. They usually also combine some disadvantages of each of the two modes they incorporate (5, section 6.2.1). One of the best examples of this is the trolleybus. It combines some advantages of buses over rail systems (greater compatibility with street traffic, better adhesion) with some advantages of rail modes over buses (electric traction with better performance and environmental aspects, stronger public image due to overhead wires). But the trolleybus also incorporates some disadvantages of the two: smaller capacity of buses and somewhat higher investment costs and dependence on fixed guideway of the rail modes.

The relationship of a transit mode with the other modes most similar to it depends on the significance of its advantages and disadvantages compared to

FIGURE 2 O-Bahn guideway entrance *(1)*.

FIGURE 3 O-Bahn guideway and articulated vehicle in Essen *(1)*.

those of each other mode. This relationship determines the potential a mode has for applications in urban transportation.

The O-Bahn, which combines highway and guided technology and uses rights-of-way C, B, and sometimes A, obviously falls between bus and rail or, more precisely, between semirapid bus [bus operating partially on busways or high-occupancy vehicle (HOV) lanes] and light rail transit (LRT). Its comparison with these two modes is therefore fundamental in evaluating the feasibility and the potential for use of the O-Bahn in urban transportation.

Before this comparison, however, an analysis of the generic features of the O-Bahn system will be presented.

GENERIC FEATURES OF O-BAHN

Characteristics of Guidance

Compared to steered (highway) modes, guided modes have the following major advantages and disadvantages:

Advantages

1. Ability to use larger vehicles that have greater capacity and a more comfortable ride;
2. Ability to operate trains, resulting in much higher line capacity and lower unit operating costs (greater driver productivity);
3. Possibility of using electric traction with its numerous advantages over diesel motors (performance, cleanliness, less noise, no exhaust, safety of operation in tunnels, and so forth);
4. Narrower right-of-way, particularly useful in high-density urban areas, on viaducts, and in tunnels; and
5. Greater safety due to positive guidance and possible fail-safe signaling.

Disadvantages

1. Requires higher investment; therefore network extensiveness is more limited;
2. Less compatible with other traffic in street operation;
3. More difficult (often impossible) rerouting (e.g., temporary detours); and
4. Vehicles cannot pass each other unless off-line stations are provided [a stalled transit unit (vehicle or train) cannot be bypassed; it must be pushed].

These differences exist between exclusively steered and exclusively guided modes--each one is designed to take full advantage of the respective technology. Examples are LRT (or rapid transit) compared with bus (regular or semirapid, standard or articulated vehicles). Modes between these two, such as trolleybus, O-Bahn, and Railbus, have some but not all of these advantages and disadvantages.

O-Bahn is actually a standard bus with the added capability of guided operation. This capability gives it some of the previously listed advantages and disadvantages, but its basic vehicle design as a bus--imposed by its street operation--prevents other distinctions, both advantageous and disadvantageous. A review of the previously listed items produces the following results.

Advantages 1 and 2, operation of larger vehicles and trains, are not used because the vehicle is a standard (or articulated) bus; manpower is not reduced--drivers continue to drive, but without the steering function on the guideway.

With respect to riding comfort, O-Bahn is considerably better on the guideway than on streets because of better surface quality and alignment geometry, but the difference in comfort between O-Bahn and bus on busways with similar construction quality and alignment is quite small.

Advantage 3, electric traction, is not used in the basic O-Bahn version; an optional version of dual-mode or trolleybus vehicles will be discussed later.

Advantage 4 is a distinct feature of the O-Bahn: due to the guidance, its right-of-way and free profile are narrower than those for a bus on a street. The inside gauge of the guideway is 2.60 m and overall width of the guideway structure (such as built in Adelaide) is approximately 3.00 m, compared to street or highway lanes of 3.25 to 3.75 m (plus shoulders, if any). In general, there is a saving in width of approximately 0.80 to 1.20 m per direction. Tunnel profile for O-Bahn is foreseen as a 4.40-m-diameter circular tube that is similar to rail system tunnels, which vary from the minimum of 3.85 m for the London "tube" system to 4.88 m for the Toronto rapid transit. This comparison is shown in Figure 4(A). Standard (unguided) buses need wider rights-of-way than LRT or rapid transit, particularly for high-speed operation for which O-Bahn is proposed. As shown in Figure 4(B), the width of aerial structures of O-Bahn is somewhat greater than the widths for rail systems. O-Bahn is shown with 3.90 m for 2.50-m-wide vehicles, LRT with 3.75 m for 2.65-m-wide vehicles, and rapid transit with 4.00 m for 2.90-m-wide vehicles.

Advantage 5, safety, is greater with O-Bahn on guideway than with standard bus on busway because of the positive guidance; it is not as high as it is for rail because O-Bahn does not have signals or fail-safe mechanisms.

Disadvantage 1, high investment, is a major disadvantage of the O-Bahn guideway compared to street lanes. As they are for all separate transit ways, acquisition and construction of right-of-way are usually the main investment cost items of the system. Guideway construction for the O-Bahn is more complicated than for a conventional roadway due to the high precision of alignment required to avoid shocks through the guidance mechanism.

Disadvantages 2 and 3, mixing with other traffic and possibility of reroutings, do not apply to the O-Bahn; with their dual-mode ability, buses can simply be diverted from the guideway to other streets.

Disadvantage 4, no passing on the guideway, is a distinct disadvantage of O-Bahn compared to buses. O-Bahn is more sensitive to this problem than are rail modes because of the lower capacity of its units and the resultant higher frequency of operation. To achieve higher capacity, off-line stations must be built, requiring additional space, switches, construction cost, and some operational disturbance.

In review, the guidance feature of the O-Bahn gives this system some of the advantages and disadvantages of the fixed guideway mode, but the most important features of that mode of operation (higher capacity, labor productivity, electric traction, lack of noise and exhaust, and so forth) are not captured by the O-Bahn.

Vehicle Variations and Additional Components

O-Bahn designers have developed several other versions of vehicles and components that are intended to improve some aspects of O-Bahn's performance or reduce some of its shortcomings.

Dual-Traction Vehicle

An articulated O-Bahn vehicle with diesel and electric propulsion has been developed. This vehicle is a combination of the conventional diesel bus and trolleybus and can switch between the two types of propulsion. Given the recent development in Germany of automatically rising trolley poles, this change of propulsion is rather simple.

Several such diesel-electric propulsion vehicles without the guidance option have been tested in recent years. These tests have shown that this type of dual-mode vehicle allows the use of each type of propulsion where it is advantageous: diesel on lightly traveled line sections in suburbs, electric on heavily traveled lines, in environmentally sensitive areas, and even in tunnels. The costs associated with this diversity are a more expensive vehicle, more complex maintenance, and somewhat more complicated operations.

The same advantages and disadvantages are valid for the O-Bahn dual-powered vehicles, with an additional advantage that O-Bahn's guidance and trolleybus mode (electric propulsion) eliminate some of the major obstacles to operation of diesel buses in tunnels--problems of wide right-of-way, exhaust, and noise--and make limited tunnel operation possible.

Double-Articulated Electric-Only Vehicle

Daimler Benz has also developed a bidirectional four-axle double-articulated vehicle with guidance mechanisms for all axles. The vehicle resembles two articulated buses connected back-to-back. Its middle section, between articulations, however, has no wheels--it is supported by the two outside two-axle bodies. The vehicle has only electric traction and it cannot be operated in steered mode: it can travel on guideway only. Supposedly, such vehicles could be coupled in trains.

The basic intention of this type of vehicle is to overcome the low capacity of standard and articulated buses and to create an image that O-Bahn is an expandable system.

However, this concept has virtually no practical value because it lacks the main positive feature of the O-Bahn--its ability to operate in both steered and guided modes. This four-axle vehicle could be operated only on right-of-way category A (i.e., in rapid transit mode). Thus it would not be in the class of medium-investment semirapid transit (semirapid bus, O-Bahn, and LRT); instead, it would be a kind of rapid transit, requiring a much higher investment. Actually, except for similar technology (vehicle construction and type of guidance), such a system would have little in common with the basic O-Bahn concept--dual-mode operating capability.

M.A.N. developed a different type of high-capacity vehicle: a double-articulated regular diesel bus. It looks like an articulated bus with an additional joint and rear section attached to it. With the O-Bahn guidance mechanism this vehicle represents a higher capacity O-Bahn, retaining its basic dual-mode capability. For street operation, however, this vehicle is somewhat bulky.

Exhaust Gas Extraction System

A special mechanism for collecting exhaust gases in tunnels has also been recently developed. It consists of an overhead tube, which is installed on tunnel ceilings, with a slot on its bottom; a specially designed bus exhaust pipe located on the roof sends exhaust into the tube, facilitating exhaust extraction. This system may be useful where opera-

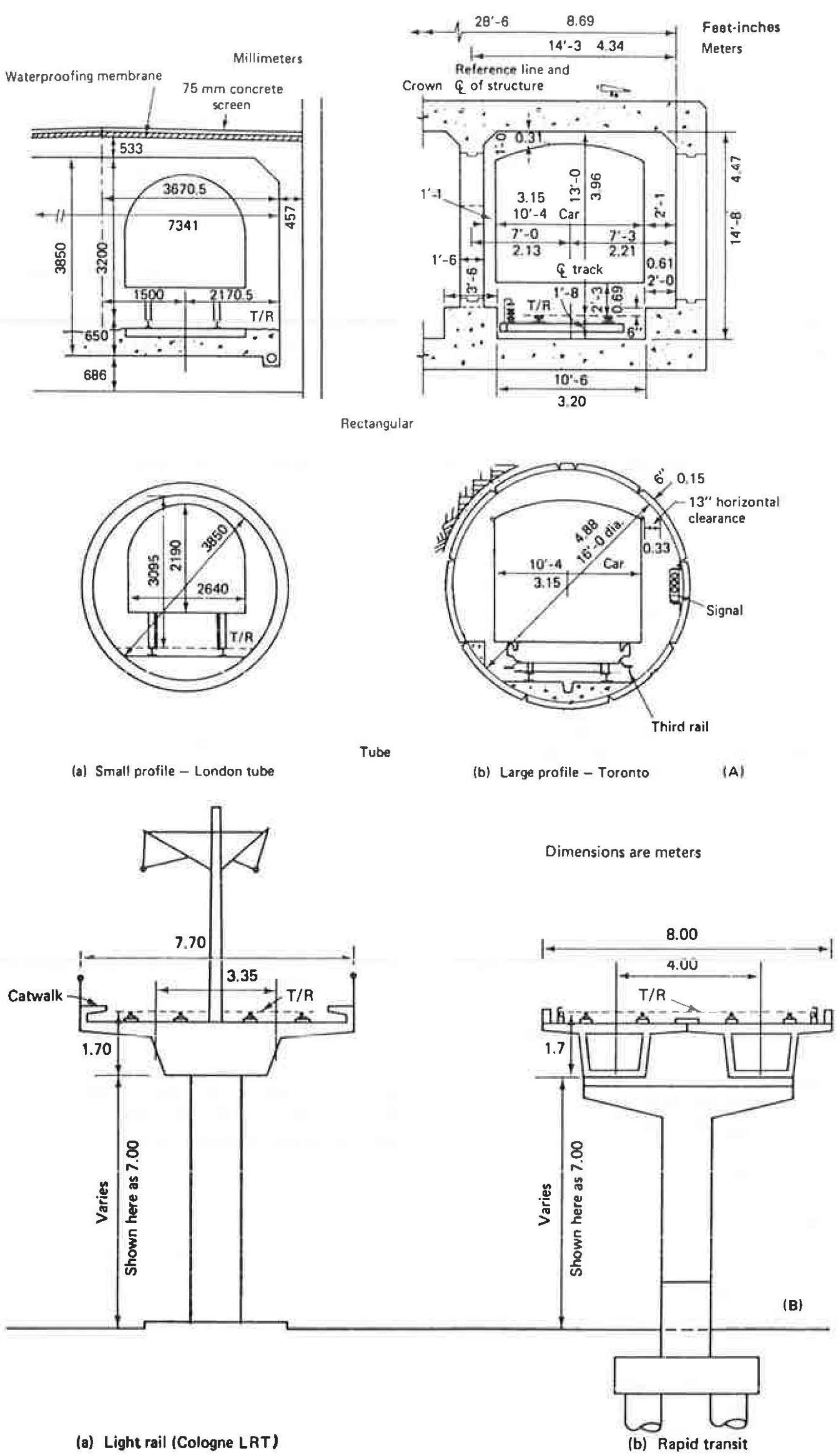

FIGURE 4 Comparison of right-of-way structures for O-Bahn, LRT, and rapid transit.

tion of diesel buses through short tunnels cannot be avoided.

Prefabricated Elements for Guideways

Developed for the O-Bahn guideway, this type of structure is claimed to result in cheaper and faster construction. This is not, however, an exclusive feature of the O-Bahn; it could be applied to construction of any other guideway or roadway type.

COMPARISON OF O-BAHN WITH OTHER MODES

On the basis of the previously defined characteristics of the O-Bahn, it will be compared in this section with its "neighbors" in the family of transit modes.

O-Bahn Versus Semirapid Bus

First, clarification of the term "semirapid bus" will be useful. The commonly used term "buses on busway" is a misnomer. Most lines to which it refers use not only busways but also HOV lanes and bus lanes on streets as well as regular street lanes. The term "express bus" refers to bus lines with limited stopping, not necessarily with any right-of-way separation. Therefore, bus lines with substantial portions of their lengths on partly or fully separated rights-of-way (category B or A, respectively) will be designated here as "semirapid bus" (5, Chapter 2).

O-Bahn compared with conventional semirapid bus, has the following advantages:

1. Narrower right-of-way,
2. Greater safety (full lateral control), and
3. Somewhat better riding quality.

The disadvantages of O-Bahn are

1. Higher investment (more complicated and precisely built guideway, more complex vehicles);
2. Lower capacity; express operation not possible (no overtaking); to correct these problems, all stations must be off-line, which involves additional costs; and
3. Lower reliability: a stalled vehicle cannot be bypassed, it must be coupled and pushed.

The O-Bahn guideway cannot be used by other vehicles. This is an advantage with respect to pressures to convert busways into HOV roadways, which have prevailed in most of our cities but which are clearly damaging to transit services. The guideway is a disadvantage with respect to use by emergency vehicles (police, ambulances, and so forth). The former is usually more important than the latter.

This comparison clearly shows that the O-Bahn is not distinctly different--superior or inferior--from semirapid bus. Mainly, the guidance brings this system the advantage of narrower right-of-way and safer operations; however, these advantages are countered by higher investment costs, lower capacity, and lower reliability. The relative importance of these factors under specific conditions determines which mode is superior to the other in each individual case.

O-Bahn Versus Light Rail Transit

The differences between these two modes are summarized in this section.

Advantages

O-Bahn has the following advantages in comparison with LRT:

1. Requires fewer transfers;
2. Requires somewhat lower investment; and
3. For new lines, involves considerably less complex new technology.

Disadvantages

1. Has much lower capacity;
2. Has higher operating costs for larger passenger volumes (more labor intensive);
3. Is less comfortable (less spacious vehicles, less stable ride during operation on streets where O-Bahn guidance is physically impossible);
4. Has lower performance due to diesel traction;
5. Has stronger negative environmental impacts (greater noise, exhaust, aesthetics of guideway);
6. Has lower reliability (electric vehicles have fewer breakdowns; if stalled, rail vehicles can be coupled and pushed more easily than buses); and
7. Is appropriate for tunnel operation only with special technology and auxiliary systems.

By far the most important advantages of the O-Bahn are its ability to branch out into regular streets (therefore fewer passenger transfers) and its somewhat lower investment costs and construction complexity (change of technology from buses to O-Bahn is small; change to LRT is drastic). The exact difference in investment costs depends greatly on the type of right-of-way and various auxiliaries. For the same type of right-of-way (at-grade in open field, aerial, and so forth), the difference, if any, is actually quite small and most of it is due to LRT electrification, which results in superior performance, or signaling, which increases safety. Major differences come if O-Bahn sections running on the street are compared with LRT in tunnels, as was the case in Adelaide (6,7); however, in such cases the tunnel brings with it much higher system performance. Indications are, therefore, that investment costs for comparable rights-of-way are somewhat but not drastically lower for the O-Bahn.

Reviewing the disadvantages of the O-Bahn compared to LRT, it can be seen that they are similar to those of semirapid bus compared to LRT. Smaller transit units (the price of street-running capability) and diesel propulsion limit the comfort (spaciousness) and performance of the O-Bahn (capacity even lower than for standard buses), and O-Bahn retains the problems of noise and air pollution.

Summary of Comparisons

To give a complete overview of the relationship of these modes, all major features in which they differ are given in Table 1 and compared using regular bus on streets as the basis (this resembles the typical planning situation of analyzing alternatives for upgrading an existing bus line).

By its very nature, this type of comparison cannot be absolutely exact; it depends heavily on underlying assumptions and, in a few items, on some-

TABLE 1 Semirapid Transit Modes (Semirapid Bus, O-Bahn, and Light Rail Transit) Compared with Regular Buses

Item	Semirapid Bus	O-Bahn	Light Rail Transit
System and operation			
Capacity	+	0	++
Right-of-way width	0	+	+
Dynamic performance	0	0	+
Permanence of right-of-way exclusivity	+	++	++
Tunnel operation ability	0	+	++
Safety	+	++	++
Need for new technology	0	-	- -
Level of service			
Need to transfer	0	0	- -
Reliability of service	++	+	++
Comfort (seats, riding)	+	+	++
Costs			
Investment cost	-	-(-)	- -
Operating cost	+	+	++
Impacts			
Image, land use impacts	0	+	++
Noise	0	0	+
Exhaust	0	0	++

Note: - - = very much inferior, - = inferior, 0 = no difference, + = superior, and ++ = very much superior.

what subjective judgments. In the present comparison the following underlying assumptions were made:

- All these modes would use similar rights-of-way and stations (except for specific physical characteristics of each mode); in other words, the portions of right-of-way categories C, B, and A for all these modes are similar.
- Design passenger volumes are substantial (otherwise semirapid transit modes would not be considered).
- Operations are as practiced on modern systems of each type (e.g., LRT has signals for sections with speeds greater than 70 km/hr).
- Quality of technology of each mode is typical of well-designed and maintained systems.

To avoid an unjustified impression of great precision, minus signs, zeros, and plus signs are used in the comparison. The more desirable characteristics are marked by plus signs and the less desirable ones by minus signs. Thus, higher costs, because they are less desirable, are designated by a minus sign. The ratings are based on the preceding analyses and comparisons of the three modes.

The comparison given in Table 1 shows quite clearly that the O-Bahn is quite similar in most characteristics to the semirapid bus: there are only a few differences in evaluations (counting these should be resisted because of their different relative weights). Comparing O-Bahn with LRT, on the other hand, shows many differences that resemble the differences between semirapid bus and LRT.

It can be concluded that the O-Bahn concept is much more similar to (and therefore competitive with) semirapid bus than to LRT.

PROSPECTS FOR O-BAHN APPLICATIONS

A review of present applications of the O-Bahn system will be useful for evaluating the prospects for its further use.

Present and Proposed O-Bahn Applications

Three cases of O-Bahn applications will be reviewed: in Essen, Federal Republic of Germany; Adelaide, Australia; and Regensburg, Germany.

Several different installations have been built in Essen to test various features and variations of the O-Bahn system. One O-Bahn line section (Fuleruner Strasse) has been in operation since 1981; joint operation of diesel and dual-traction vehicles with LRT on the same right-of-way has been tested [joint operation of conventional buses and LRT has existed for many years in Amsterdam, Hannover, Munich, Pittsburgh (tunnel) and many other cities]; operation of dual-traction vehicles in LRT tunnels will also be tested. The installations in Essen have thus been quite useful for testing and development of various physical and operational elements of the O-Bahn system.

Adelaide has under construction a long radial line along an unused freeway corridor into the center city; in the suburbs and in the center city buses branch out on streets. The line is heavily line-haul oriented with only three stations (off-line) and two guideway entrances for collector routes.

In arguing for the O-Bahn system compared to semirapid bus and LRT (the debate was finally aligned with political parties and the O-Bahn was adopted when the party supporting it won elections), its proponents quoted several advantages. O-Bahn has a narrower right-of-way than a conventional busway would have required; O-Bahn is safer because of guidance, particularly at the planned speed of 100 km/hr; it is quieter; and it requires a substantially lower investment than does LRT (although higher than semirapid bus).

However, the information about that project (6,7) and some observers point out that saving 1 or 2 m of right-of-way width in a 50-m-wide unused freeway right-of-way is insignificant; safety against head-on collision is greater, but it may be questionable whether manual-visual operation of guided vehicles at 100 km/hr is safe against rear-end collisions; vehicle noise actually cannot be changed much because the same diesel engine and wheels produce it regardless of guidance; capacity and flexibility of operation are lower for O-Bahn than for bus; and finally, the massive guideway structure (Figure 5) is much less aesthetically pleasing than either a blacktop roadway with attractive pavement markings or LRT tracks that can be constructed as a green surface with four rails and a pair of overhead wires only. (Other aspects of a bus and LRT comparison for the Adelaide line exceed the scope of this paper.)

Consequently, the case of O-Bahn in this particular application is so weak that this specific project may damage not enhance O-Bahn's chances for other adoptions.

Regensburg, a small city (140,000 population) in Germany with a high density of activities and narrow streets, has many buses converging on its central area. A 1.6-km-long tunnel has been proposed to take several bus lines through the center, thus increasing their speed and reliability.

This is a case in which the narrower right-of-way of the O-Bahn would be a major advantage. If the cost and the historic nature of the area permit construction of the tunnel and purchase of special vehicles and if the problem of exhaust gas extraction can be technically solved, this application of the O-Bahn may be more appropriate than those in outlying areas of cities, such as in Adelaide.

Review of Deciding Factors

The basic question in considering the O-Bahn for any specific application should be its differences with respect to semirapid bus. Because the differences in riding quality and safety are usually of secondary importance, the basic trade-off is that of the narrower right-of-way and guaranteed right-of-way exclusivity of the O-Bahn versus lower cost, higher capacity, and flexibility that favor semirapid bus. Comparison of LRT with semirapid bus will in most cases be similar to that of LRT with O-Bahn.

Thus, the two most important factors that may justify use of the O-Bahn are

- Narrower right-of-way, and
- Need to ensure a permanent exclusive transit facility.

This leads to the following conclusions about prospects for the O-Bahn system.

CONCLUSIONS

In developing countries there is a pressing need to provide high capacity on a substantial network with reasonable reliability, speed, and comfort with rugged and economical operation. Because it has the lowest capacity of the three modes, higher investment cost than semirapid bus, and higher operating cost than LRT, O-Bahn does not appear to be a com-

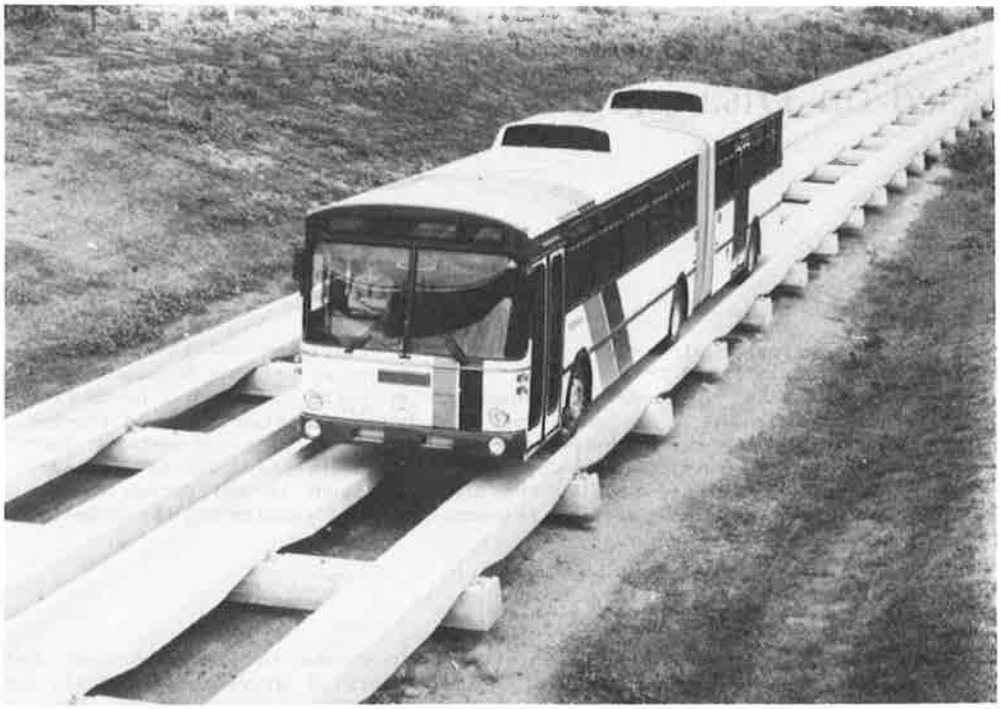

FIGURE 5 O-Bahn guideway in Adelaide: questionable aesthetics *(6)*.

petitive system. There is no way that O-Bahn could handle the volumes buses carry in Bogotá, Bangkok, or São Paolo.

In West European countries there are cases where narrower right-of-way is extremely important because of restricted space. A typical case would be convergence of several lines on a separated right-of-way section (guideways cannot be used on streets) similar to the situation in Regensburg. O-Bahn may be the optimal mode for such corridors.

In the United States the importance of ensuring permanently exclusive right-of-way may appear as a more important factor favoring O-Bahn than narrower right-of-way. Safety may also be important, but mostly on lines with moderate frequencies of operation because O-Bahn is less suited to short headways than is conventional bus.

It can be concluded that the O-Bahn system represents an option or accessory of the bus transit mode that provides higher quality (although not higher capacity) of service at a higher cost than semirapid bus. If evaluated on its technical and functional merits, the O-Bahn appears to be applicable only to special conditions such as convergence of many bus routes in one or two corridors in downtown areas.

REFERENCES

1. The O-Bahn, Testing and Application of the Track-Guided Bus. Daimler-Benz AG, Stuttgart, Federal Republic of Germany, 1982.
2. H. Christ. The O-Bahn, an Economical and Flexible Local Transport System. Presented at the Annual Transportation Convention, Johannesburg, South Africa, 1983.
3. M. Krueger. Spurfuehrung von Stadtbussen: Stand der mechanischen und der elktronischen Spurfuehrung. Verkehr und Technik, Vol. 4, 1983, pp. 111-119.
4. H. Drewitz and M. Krueger. The Place of the Guided Bus Inside of M.A.N.-Bus Transport System. Proc., Conference on Advanced Rapid Transit Systems, Amalfi, Italy, 1983.
5. V.R. Vuchic. Urban Public Transportation Systems and Technology. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1981, 672 pp.
6. K. Niemann and H.-A. Sack. Project und erste Erfahrungen beim Bau einer O-Bahn Strecke. Der Nahverkehr, Vol. 6, 1983, pp. 54-61.
7. F.A. Wayte and M.M. Starrs. Adelaide's O-Bahn Busway Experiment. Built Environment, Vol. 8, No. 3, 1982, pp. 197-204.

Publication of this paper sponsored by Committee on Bus Transit Systems.