LINDENWOLD RAIL LINE AND SHIRLEY BUSWAY: A COMPARISON

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Comparisons of different transit modes have seldom given sufficient attention to service parameters. Rather, costs were compared for modes that optimally provide different types of operations. This study utilizes 2 existing systems for a comprehensive comparative study of bus and rail technologies and their different types of operations. It differs from previous studies in 2 respects: First, it performs the analysis on 2 actual systems and thus does not utilize any hypothetical assumptions. Second, it includes more system characteristics than any of the previous studies. The Lindenwold "Hi-Speed Line" offers all-day, high-frequency, reliable service among its 12 stations; it depends heavily (80 percent) on access by automobile. The Shirley Busway provides mostly peak-hour service on very many lines with different routings, but with a lower frequency and reliability than Lindenwold; it relies mostly (84 percent) on access by walking. Lindenwold required very high investment and was completed as one project; its revenues exceed operating costs by a significant amount. The line is extremely well operated and managed. Shirley was introduced with considerably lower investment, but it requires at least a 3 to 5 times higher labor force per passenger than Lindenwold. Its revenues closely cover the operating costs. Lindenwold attracts a 70 percent higher ridership than Shirley. Shirley can be improved by the introduction of all-day high-frequency service on some of its routes. The main deficiency of the busway concept will remain street operation in the CBD. Both systems are very successful. Their attraction of new riders proves that there is a considerable latent demand for transit, even in low-density auto-oriented suburban areas, and an underutilized potential of modern bus and rail modes.

•THE NEED for provision of high-type transit service on predominantly or entirely separated rights-of-way has been recognized throughout the world as imperative for modern transportation in large and medium-sized cities. The optimal domains of rail rapid transit, light rail, and different bus operations are often misunderstood, and their definition requires additional analysis.

Yet, comparison of different modes of transportation is quite a complex problem, and the tendency of past studies has been either to simplify it to a consideration of only a few or even one parameter (usually cost) or to use a theoretical model that in most cases does not represent reality in some important aspects. Both simplifications result in incorrect conclusions.

Two recently introduced transit systems, the Lindenwold Rail Rapid Transit Line between the New Jersey suburbs and Philadelphia's city center and the Shirley Highway Express Bus Lines between the Virginia suburbs and Washington's city center (for convenience the 2 systems will be referred to as Lindenwold Line and Shirley Busway) are so similar in the service they are intended to provide that they represent an excellent real case for a comparison of bus and rail modes.

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PREVIOUS STUDIES

A number of studies have compared urban transportation modes or technologies. Several typical ones will be discussed and evaluated here.

Leibbrand, in a study for Frankfurt, Germany (9), analyzed 4 different modes: rapid transit, light rail, Alweg monorail above ground, and Alweg in tunnels. Although similar networks were assumed for each technology, each system was adapted somewhat on the basis of its own characteristics and given conditions. The analysis was rather comprehensive; the only criticism might be that quantitative items, and particularly cost, had a very dominant role in the evaluation.

De Leuw, Cather and Company (5) recently performed for Manchester, England, a comprehensive comparative study of rail rapid transit, Safege, Alweg, and Westinghouse Expressway for a proposed rapid transit line. The different technologies were evaluated with respect to the state of their development and the technical characteristics of vehicles and guideway. However, service characteristics were only briefly mentioned, and great emphasis was placed on environmental aspects. The relative weight given to these aspects as well as cost might be questioned.

Deen and James (4) used a theoretical model to make a comparison of bus and rail modes for line-haul service in Atlanta. The authors emphasize that "it was essential to ensure equal service for bus and rail systems being compared". This approach is, however, conceptually incorrect. A hypothetical vehicle design used for the bus without realistic associated costs and the little attention given important service parameters made the comparison unrealistically favorable for the bus. The authors recognized these shortcomings and placed considerable emphasis on the analysis of influence of change in conditions on relative advantages of each mode.

Fehr (6, 7) recently completed for the Boston Transportation Planning Review a study of 9 alternative modes and/or types of operations for outer sections of a rapid transit line. The inherent differences of each mode were respected and the value of higher speed was suitably acknowledged. A deficiency of the study was that qualitative facts were virtually disregarded and cost was again the overriding concern.

One study (1) used a hypothetical model for comparisons of private automobile, bus, and rail. Assumptions were made stipulating service parameters to match as much as possible those of the private automobile. This does an injustice to the public transportation modes, particularly since system aspects (i.e., reliability, capacity, space limitations, environmental impacts) were disregarded. The evaluation of the modes was based exclusively on cost.

Another study (2) presented the most comprehensive conceptual framework for comparison of modes. The study gave an excellent theoretical basis, although the suggested methodology was not brought to an operational form.

It is not known whether any comprehensive study has been undertaken to compare modes on the basis of real systems already in operation. However, it can be concluded that studies comparing different modes suffer from some of the following deficiencies:

1. The models used are incorrect when they force identical types of operation on modes that inherently operate optimally in different ways.
2. The models used are not comprehensive enough; many factors important in real life are "assumed away".
3. Many important parameters are not given adequate consideration, and dominant, often exclusive, weight is given to cost.
4. One of the basic objectives of public transportation systems—to transport the maximum number of passengers—is disregarded.

LINDENWOLD RAIL LINE AND SHIRLEY BUSWAY

The Lindenwold Line (Fig. 1) was constructed between 1966 and 1969. Utilizing existing subway tunnels in downtown Philadelphia and Camden, the line extends on a private right-of-way southeasterly to Lindenwold, New Jersey. The line serves a total of 12 stations 24 hours a day. No bus feeders were provided until recently, and the line relied for access predominantly on the private automobile from the relatively low-density

areas it serves. On October 28, 1972, bus routes paralleling the line were converted to feeder routes.

The first 5-mile section of the Shirley reversible-lane busway in the center of Interstate 95 (the Henry G. Shirley Memorial Highway) south of Washington, D.C., was opened in 1969 (Fig. 2). By April 1971 a temporary busway was completed for the remaining 4 miles to the center span of the 14th Street Bridge. Subsequent improvements were achieved by construction of a bus ramp in Springfield, Virginia (11 miles from the Potomac), and reserved bus lanes in downtown Washington. At present the Shirley Busway consists of a number of bus lines that operate on various routes through the Virginia suburbs and then enter the exclusive lanes on Shirley Highway. No stations are provided along the way; in downtown Washington the lines split into 3 groups. At times other than peak periods most of the lines do not operate; a few operate on local streets.

By far the largest user of the busway is AB&W Transit Company, with approximately 84 percent of the bus trips. The remaining trips are composed of WV&M Transit Company, Trailways, Greyhound, charter, and Armed Forces buses. The regular AB&W fleet has been augmented by the use of 76 modern, specially designed buses purchased by the Northern Virginia Transit Commission (NVTC).

PURPOSE AND SCOPE OF THIS STUDY

The basic characteristics of the Lindenwold Line and Shirley Busway, given in Table 1, clearly show the great similarity between them. Both systems serve, with the exception of the city of Camden, relatively low-density, middle- to high-income, auto-oriented suburban residential areas. Both have highly peaked demands.

The Lindenwold Line competes against relatively fast driving conditions but with bridge tolls and expensive parking in the CBD. Shirley Highway at present has very poor driving conditions on automobile lanes, but a considerable amount of parking in the city is provided free or at a nominal charge by government agencies.

The basic operational characteristics of both systems are given in Table 2. Both systems represent in many respects the latest in technology and operations of the 2 modes. Lindenwold Line, with its high automation, high speed (maximum 75 mph), extensive parking facilities at stations, and competent management, represents the latest in rail rapid transit. Shirley Busway lines, operating in good part on an exclusive right-of-way but utilizing the capability of buses to branch out in suburbs to different lines and operating on reserved bus lanes downtown, represent what is often defined as the optimal bus semi-rapid transit system. Consequently, Lindenwold Line and Shirley Busway represent the best real case anywhere in the country for comparing the two modes with respect to their effectiveness in providing modern transit service. The purpose of this study is to make such a comparison on a comprehensive basis.

The study data have been obtained from many sources, but mostly from the managements of the Lindenwold Line and several agencies in charge of operations utilizing the Shirley Busway. Because of the complexity of the busway system and multiplicity of parties involved, some data desired for the Shirley Busway either do not exist or could not be obtained, especially for the relatively small number of buses not operated by AB&W that also use the busway facilities.

COMPARATIVE ANALYSIS

There is no standard, generally adopted theoretical method for the comparison of different modes of transportation. To ensure a systematic and comprehensive review of all characteristics, requirements with respect to the systems have been classified by "interested parties"—passengers, operator, and community:

Passenger	Operator	Community
Availability	Area coverage	Quality of service
Speed (travel time)	Frequency	System impact
Reliability	Speed	Passenger attraction
User cost	Reliability	
Comfort	Cost	
Convenience	Capacity	
Safety and security	Safety and security	
	Side effects	
	Passenger attraction	

Figure 1. Philadelphia: The Lindenwold Rail Line.

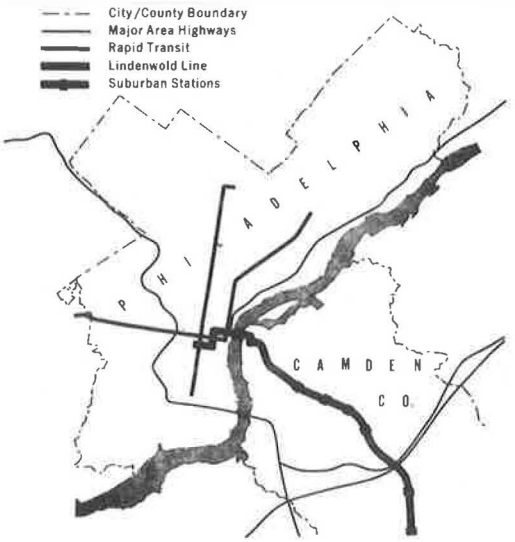


Figure 2. Washington, D.C.: The Shirley Busway.

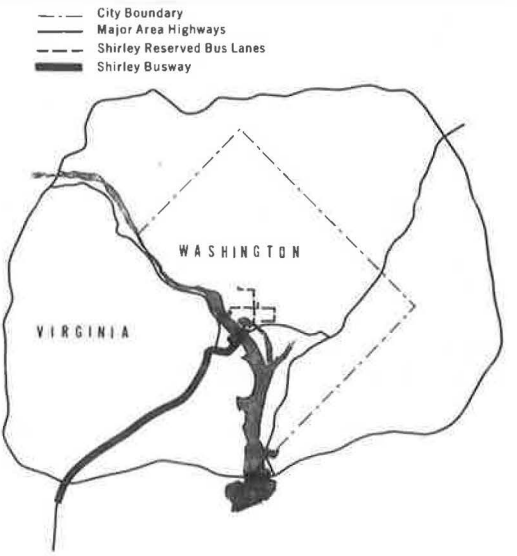


Table 1. Basic system characteristics.

Characteristics	Lindenwold Line	Shirley Busway
Location	From southern New Jersey northwest into central Philadelphia	From northern Virginia northeast into central Washington
Types of lines	Radial via bridge to CBD	Dispersed, then radial via bridge to three central employment areas
Type of service		
Line-haul	Rail	Bus on buswav
Access modes (percent)		
Feeder transit	9	0
Park-and-ride	37	8
Kiss-and-ride	43	8
Walk	11	84
Percent changing vehicles	89	16
Downtown distribution	4 stations, discount on transfer to rapid or surface transit	Stops along 15 blocks, possible transfer to surface transit
Primary service area (square miles)	130	95
1970 population (est.)	442,000	356,000
1970 population density (est. persons per square mile)	3,400	3,750
Average cars per household	1.3	1.5
Employment centers served (1975 jobs)	Central Philadelphia (380,000) Camden, New Jersey (45,000)	Central Washington (400,000) Crystal City (40,000) Pentagon (20,000)
Opening Date	February 1969	September 1969

Each requirement will be defined and then both systems will be examined with respect to it. Reliability, safety and security, and passenger attraction are discussed only once to avoid duplication. A concluding table is given in which the findings of evaluation are summarized. The discussion is based on this table, i.e., on the evaluation of the different requirements. No effort is made to give relative values to the parameters in a quantitative way, nor is an attempt made to find an overall quantitative measure for each of the 2 systems. Rather, it is considered more valuable that the reader have a clear overview of the 2 systems with respect to each requirement so that he can judge its relative significance for the specific situations he wishes to analyze.

ANALYSIS OF PARAMETERS: PASSENGER

Availability

Availability to the passenger, without which the population cannot use a transit system, has 2 facets: locational—closeness to the system's terminal—and temporal—frequency of service. For good availability, users must have both close terminals and high frequency of service. Because of cost constraints, trade-offs between the two must be made. At one extreme is a dense network with low frequency; such a system is not available for long intervals of time. At the other extreme is frequent service to few points; users far from terminals do not have the service unless they use feeders. Availability for the 2 systems is shown schematically in Figure 3.

Lindenwold—The Lindenwold system has a line-haul service with few outlying stations and a short distribution segment within the center city of Philadelphia. Area coverage is now provided by walking, bus, and automobile. However, bus feeder service carries only 9 percent of the total, so that area coverage in the suburbs is still predominantly provided by the automobile—kiss-and-ride, 43 percent; park-and-ride, 37 percent. Walking and bicycling combined amount to 11 percent. At present 8,800 parking spaces are available (Lindenwold Station alone has 2,202 spaces, of which 1,070 are free and 1,132 require a 25-cent fee during the morning peak). Parking at some stations is still inadequate. For persons beyond walking distance who do not have automobiles, availability is limited to bus service, which is often unsatisfactory. The feeder bus system consists of 20 routes during off-peak hours, 13 during the peaks (the line does not have capacity to accept riders from all routes). Frequencies are generally low.

The line-haul portion of the system offers a high frequency of service—headways are 10 minutes or less between 5:20 a.m. and midnight, with hourly owl service afterwards, except on Sundays, when headways are 10 to 15 minutes.

Downtown distribution is not fully satisfactory because the stations are located 2 to 4 blocks away from the main employment centers and shopping areas, i.e., at a moderate walking distance. Reduced fares are provided for transfers to several SEPTA lines, including the 2 subway lines.

Shirley—AB&W Transit Company operates 9 major routes using the Shirley Busway for the line-haul portion. Each of these routes in turn represents a family of collection and distribution route options that branch out over a large area. The purpose is to increase area coverage, but it does so at the expense of frequency of service. An example will show the character of Shirley Busway services. During the 2 peak periods Route No. 7 carries 5,761 passengers—29.7 percent of the busway's AB&W peak-period total—and has a total of 48 routings. (Figures are based on October 10, 1972, summary totals, which showed 19,413 peak-period AB&W riders entering south of the Mixing Bowl.) One-half the schedule for this line is reproduced in Figure 4. Many of the subroutes operate during 1 peak period only; thus, 21 subroutes of Route No. 7 have a total of only 12 departures during the morning peak period. Average morning peak headways for the large subroutes are between 11.3 and 18 minutes. Other routes are similar in nature. There are no stations along the busway.

Each bus follows 1 of 3 routings within the central city, serving a set of stops along 2 to 3 miles of local streets before terminating at 1 of 3 terminals.

The splitting of routes is so excessive that frequency on most of them is highly unsatisfactory (once per day in some cases). In off-peak hours and on weekends only a

small number of lines even operate, and some of them run on local streets, thus offering a different, much lower level of service. Park-and-ride and kiss-and-ride are used by only 16 percent of passengers, who utilize 3 designated park-and-ride facilities with a total capacity of 480 spaces; the remaining cars are parked on suburban streets and other areas about which there is no information. Consequently, the availability of service is excellent for persons who live within walking distance of the lines and travel at the times a bus for their desired destination is scheduled. For those traveling at other times or to other terminals and for those residing beyond walking distance of a line, availability is inadequate; a relatively small group of these use automobiles for access to bus lines.

Comparison—The Lindenwold Line, in combination with private automobiles and buses as feeders, offers a considerably higher availability than the Shirley Busway (required transfers are a factor in speed and convenience, not availability).

Speed (Travel Time)

The total door-to-door travel time is composed of 5 parts: access, waiting, transfer, travel, and departure times. Relative weights of these time intervals vary since passengers perceive them differently. Therefore, based on various studies reported in the literature, a factor of 2.5 is used in this study for waiting and transfer times to obtain perceived travel times.

Lindenwold—For the commuter residing 3 miles beyond the Lindenwold station, approximately 47 minutes are required for the morning peak-hour drive to the Philadelphia CBD, including parking. The same journey using the Lindenwold park-and-ride or kiss-and-ride facilities requires 35 actual minutes, or 42 perceived minutes.

Shirley—Because the uncongested busway allows its users a full view of the auto congestion they are bypassing, perceived travel times are shorter than actual times. The latter are for most users from 10 to 30 minutes below comparable automobile times. The greatest saving is made for commuters living south of Seminary Road. Much of the present automobile congestion on Shirley Highway is caused by construction works. After their completion the advantage of buses may be somewhat diminished.

Comparison—The absolute travel speed on the Lindenwold Line is considerably higher than on the Shirley Busway; however, the latter is superior to the former in relative speed with respect to the competing automobile travel for most peak-hour trips.

Reliability

Reliability is expressed by schedule adherence. The variance from scheduled travel times may result from traffic delays, vehicle breakdowns, or adverse weather conditions. It depends mostly on the control that exists over the system. By far the most significant factor for reliability is operation on private rights-of-way.

Lindenwold—In 1971, 99.15 percent of all trains ran less than 5 minutes late, including all weather, mechanical failure, and other delay causes. So far in 1972 the percentage figure has fallen to about 97 percent, as a result of extra passenger loads placed on the line during a 9-week bus strike, with subsequent operating delays. The line has never been seriously affected by adverse weather.

Shirley—Surveys performed on 4 different days during 1971-1972 showed that at the last bus stop in the Washington CBD, of the total 363 observed buses, 22 percent arrived before scheduled times, 32 percent were more than 6 minutes late, and only 46 percent arrived on scheduled times or up to 6 minutes later.

On several occasions of inclement weather, when transit service is most essential, major breakdowns of service on the Shirley Lines occurred. Many passengers remained stranded at stops without information that service was cancelled.

Comparison—The Lindenwold Line is clearly far superior to the Shirley Busway with respect to reliability.

User Cost

Transit fare is the most significant portion of transportation costs, but other out-of-pocket costs are also included, particularly by commuters. In a broader sense cost of

access by automobile and even its fixed costs (if the auto is owned for that purpose) should also be considered.

Lindenwold—Fares are graduated, ranging from 35 to 75 cents. Transfer to SEPTA lines in Philadelphia is given at a 50 percent discount (2 rides for 35 cents). For commuter parking close to the stations the fee is 25 cents (16 percent of all riders pay it); at off-peak hours all parking is free. The fare for bus feeders and the line is the same as it was for direct bus travel to the city. The alternative of traveling by car is in most cases higher, however, since the auto driver must pay a bridge toll (60 cents or 35 cents for commuters) and a parking fee in the Philadelphia CBD of approximately $1.75 per day.

Shirley—For short trips the fare is 50 cents and for those past the Beltway, 80 cents. Transferring among AB&W buses is free, but transferring to DC Transit in Washington allows a discount of only 5 cents. Driving by car has only parking as the out-of-pocket cost, and for many downtown employees free parking is provided.

Comparison—Lindenwold fares, particularly if transfer in the city is included, are lower. If costs of owning and operating an automobile for access are included, Shirley requires on the average a somewhat lower total cost since residential collection is included and fewer of its users must own an automobile.

Comfort

Comfort encompasses many factors. Paramount are the availability of a seat and the quality of ride (affecting user's ability to read and write). The physical comfort of the seat, geometry of the entrances and exits, width of aisles, presence of air-conditioning, jerk and noise levels, image of patrons relative to user's self-image, and degree of privacy offered all enter in.

Lindenwold—In half of the 16 trains from 7:12 to 8:37 a.m. (surveyed in June 1971), seated capacity was exceeded before the Ferry Avenue station. From there to the 8th and Market station, load factors are now often about 1.4. Beyond the latter station, seats once again become available. The time spent standing is between 9 and 13 minutes. Off-peak seating is, naturally, always ample.

The seats themselves are wide, high-backed, and comfortably cushioned. Interiors of the cars are plush, air-conditioned, clean, and well-lighted, affording the opportunity for reading. Vehicle acceleration is smooth and rapid, with high-speed operation equally smooth. Coupled with a visibly private guideway, the system generates a high level of psychological comfort.

Shirley—Riding in buses is considerably less comfortable than in rail vehicles because of the greater sway and vibrations and less space in the vehicle. An average of less than 10 percent of NVTC bus patrons must stand during the morning peak period (regular buses show a better, if still overloaded, record). Because average trip time on these buses is roughly 30 minutes, standing becomes a serious annoyance. Seventy percent of the regular AB&W buses are air-conditioned. The 76 NVTC buses offer greater comfort, wide seats, pleasing visual image, and more leg room. Operating characteristics, unfortunately, are comparable to older buses. With 57 percent of choice riders and an average user annual household income of $16,400 (October 1971), the self-image of the user should be good.

Comparison—An analysis indicates that on the Lindenwold Line 32 persons stand a total of 320 minutes per car-trip during the peak hour for an average of 2.96 minutes per passenger. On Shirley NVTC service 5 persons stand a total of 150 minutes per bus, an average of 2.89 minutes per passenger. The conditions are considered comparable. Based on the considerable advantage of modern rail vehicles over buses in riding qualities and larger space per person, it is concluded that the Lindenwold Line is superior in comfort.

Convenience

While comfort is related to the vehicle, convenience refers to the overall system. Lack of transferring is a great convenience, as are good off-peak service, clear system information, well-designed and protected waiting facilities, and sufficient, close parking (if required). By nature, discussion of conveniences is predominantly qualitative.

Lindenwold—The Lindenwold Line requires for 89 percent of its passengers a transfer from access modes. However, parking around stations means a great convenience to the users. Off-peak riders are provided with free close-in parking. The option of fare-integrated bus feeders is also a convenience. Stations are pleasing and offer good weather protection, rest rooms, automatic fare collection, and other conveniences. Information about the service is clear, simple, and available. In fact, the conveniences offered the commuter are excellent with the exception of the transfer annoyance inherent in most trips on rail commuter service.

Shirley—Besides shorter travel times, the main attraction of the Shirley service is considered to be the lack of transferring or the possibility for many passengers to walk to the stops. However, in common with most bus networks, the Shirley system bus stops generally have no weather protection, security arrangements, route information, or seating. In fact, even the AB&W management has no clear idea of where all its stops are. The published schedules are extremely complex and unclear (Fig. 4). The sketch of routings is unintelligible. In short, although lack of transferring represents a major asset, the Shirley service provides very low user convenience.

Comparison—The wider range of access mode options, simplicity of the system, clarity of information, and positive system amenities of Lindenwold outweigh the only convenience in which Shirley is superior—lack of transfers.

Safety and Security

Safety includes 2 areas: absence of accidents and protection from crime.

Lindenwold—Like all modern rail systems, the Lindenwold Line has redundant automatic safety devices, which ensure extremely high operating safety. The system's security arrangements include 24-hour closed-circuit television monitoring of all stations using 20 television screens coupled to a public address system and a police force that guards the station areas and late-night trains. These arrangements have produced a high security record and good public image.

Shirley—Operation on an exclusive busway increases bus safety, although it remains only as good as manual control allows. According to limited data, the Shirley service has shown a very high level of operational safety. Off-peak and night security for the waiting user is in some areas a serious problem.

Comparison—In both safety and security the Lindenwold Line is excellent; the Shirley Busway offers good safety, but the security of the system has a low image.

ANALYSIS OF PARAMETERS: OPERATOR

Area Coverage

With respect solely to network extensiveness, the Shirley Busway provides in outlying areas superior coverage (kiss-and-ride and park-and-ride). Although Lindenwold now has bus feeders and its facilities for access by automobile are superior, it is considered that Shirley has an advantage in this respect.

Area coverage in the CBD is adequate (but not excellent) for both systems: Lindenwold has 4 stations with numerous entrance points and easy transfer to supplementary distribution by rapid transit; Shirley has distribution along some 15 blocks (each line follows one of the 3 main distribution routings), but inconvenient transfer to other bus lines. The two are therefore comparable.

Comparison—In overall evaluation Shirley has an edge in area coverage over Lindenwold.

Frequency

As discussed under availability, frequency on the Lindenwold Line is excellent, as it is for access by car or walking. Most of the Shirley routes have very poor frequency and variable headways. It is often believed that, for commuters, frequency is not important. In reality, however, there are no residential areas in which 1, 2, or 3 departures during the whole 2-hour peak period would be convenient for all potential users. Short, regular headways are desirable for all passengers. This characteristic is prob-

ably the most serious deficiency of the Shirley Busway. Consequently, Lindenwold is clearly superior in this feature.

Speed

The operator is particularly concerned with high operating speeds on the lines, since they affect his fleet size, labor costs, fuel, maintenance, and—above all—attraction of passengers. Several speeds are used in transit systems analysis, including (a) travel speed, the one-way average speed of a vehicle including stops, and (b) paytime speed, the average speed based on the driver's paid time.

Comparison: The average speeds shown in the following table clearly indicate that the Lindenwold Line is much faster; this is one of the major factors for its operating efficiency:

Speed	Lindenwold	AB&W	NVTC
Travel	38.7	15.8	18.6
Paytime	24.2	11.3	13.5

Cost

Although cost has often been given an unjustifiably high relative weight (even used as a single evaluation criterion for different systems), it remains the single most important factor to the operator. In this analysis three aspects of costs are discussed: investment, operating cost, and revenue. Investment cost analysis is, however, very cursory since it depends so heavily on local conditions; the general value of results of such an analysis would be quite limited.

Lindenwold—The total investment for the line, including rolling stock, amounted to $94 million. This cost is, however, considerably lower than it would have been for construction of the whole facility because the existing tunnels and bridge were utilized. New investments are being planned for the purchase of additional vehicles, lengthening of platforms, expansion of park-and-ride facilities, etc. All investments have been borne by the Delaware River Port Authority.

Operating costs (not including depreciation) amounted to $4,756,407 in 1971 while the revenues totaled $4,749,635. Thus the operating deficit amounted to $6,772. Since the line carried 9,414,329 passengers, its operating costs, as well as revenues, were $0.50 per passenger and $0.06 per passenger-mile. Revenues for the line now exceed losses at an approximate rate of $1 million per year.

PATCO employs 242 persons, and thus the line carries an average of 171 daily passengers per employee. Computations for the presently planned addition of 20 cars show that 37 new employees will be needed. Based on the present car utilization rate, marginal productivity for this expansion will be 284 passengers per employee.

Shirley—It is impossible to determine even approximate investment costs of the Shirley Busway. One estimate (3) places the cost at $7.57 million for the "temporary" Busway project. There are no estimates for such costs as right-of-way, longer structures, additional ramps, etc. Another cost that cannot be determined is that of reserved lanes in the city. Total actual cost of this project would obviously be several times higher than the quoted amount. All direct investments for the project were provided by the federal government (UMTA).

Operating costs for the 76 NVTC buses were $138,493 in October 1972, while revenues amounted to $142,540, or a 2.9 percent profit. In addition, a "diversion cost" allowance collected by AB&W from UMTA for the revenue loss to the NVTC buses amounted to $37,288 in October 1972. Thus, for October 1972, per-passenger operating cost for NVTC service averaged $0.68 while revenues averaged $0.70 per passenger.

Very conservative estimates are that Shirley has at least 455 employees (administration not included). With its present ridership its labor productivity is 52 daily passengers per employee. To accommodate the same additional volume as 20 Lindenwold cars, Shirley would require an additional 114 buses and 196 employees. Under the same assumptions productivity would not change.

Comparison—It is extremely difficult to compare capital costs of the two systems; however, it is rather obvious that Lindenwold required an appreciably higher investment.

With respect to operating costs and revenues Lindenwold has better results (Table 2). Present productivity of its employees is 3.3 times higher than that of Shirley. For an incremental capacity increase of 20 rail cars (10,500 daily passengers) this ratio would increase to 5.4 in favor of Lindenwold. The high operating cost of Shirley buses is also caused by highly peaked use and very high dead mileage.

Capacity

Two different capacities can be critical for a system: line-haul capacity and terminal capacity. The latter is smaller in all cases except when vehicles from a line-haul section branch out into several terminals.

Lindenwold—Total line capacity can be conservatively estimated at 9,750 persons per hour. Present daily peak hourly volume is 8,000 persons, and some trains during intervals shorter than 1 hour are crowded. However, neither line-haul nor terminal capacity has been approached; fleet size is the bottleneck. With an additional 55 vehicles, capacity would be increased by 80 percent; lengthening of platforms, which would involve substantial works only at the terminal station, could increase it by an additional 30 percent.

Shirley—Counts indicate that approximately 100 buses (6,500 seats and standing spaces) cross the 14th Street Bridge during the peak hour and continue on the reserved lanes in the streets. They carry an estimated volume of 5,400 passengers. While the line-haul operation on the busway is far below capacity, the capacity of the terminals has almost been reached; congestion causes frequent delays and irregularities. Thus, although the fleet capacity is insufficient, the fleet could not be substantially increased without adding new terminals and street routings.

Comparison—Both systems are limited in capacity by their current fleet sizes, but Lindenwold carries 48 percent more persons per hour than Shirley. Reserve capacity of Lindenwold with fleet increase is about 80 percent, whereas Shirley could not use a major fleet increase without extension of reserved lanes and provision of new terminals. Lindenwold is clearly superior.

Side Effects

System effects on the non-users and the environment for which the operator is responsible include such physical impacts as aesthetics, noise, and air pollution.

Lindenwold—The tunnel and bridge sections have no impact; the elevated structure is aesthetically satisfactory. Noise levels are low and air pollution is nonexistent. However, although many underpasses are provided, the line has a certain dividing effect on the area.

Shirley—Busway and buses in streets are aesthetically satisfactory. Noise and air pollution by buses are considerably improved on the latest models, but they still create problems, particularly in the streets.

Comparison—Shirley buses produce more negative side effects than does the Lindenwold Line.

Passenger Attraction

The number of passengers a transit line carries is the most important single indicator of its success and its role in urban transportation. The attraction is obviously a function of the type and quality of service, but there is also an additional factor, probably best described as "system image", which can be very important. This image is difficult to define, but it is influenced by the simplicity of the system, reliability of service, frequency, and regularity as well as physical characteristics of facilities.

Lindenwold—The Lindenwold Line carries on weekdays an average of 41,500 trips. Excluding the influence of the 1972 bus strike, when trips increased to 50,000, the ridership has been steadily increasing. A certain number of persons have tried the line but did not stay with it when park-and-ride facilities were overcrowded. Each expansion of these facilities has captured some of the latent demand. Additional non-auto-owners have been attracted by bus feeders.

Shirley—Average weekday ridership is now about 20,300 AB&W passengers plus approximately 4,000 passengers from smaller carriers. Patronage is increasing steadily on most lines. Although this number far exceeds the projections for the project, it is known that considerable latent demand is not attracted because of the inadequate information and extreme complexity of the service, low frequency, and, above all, insufficient number of buses. Estimates are that because of these deficiencies several thousand persons tried the service but did not stay with it.

Comparison—Lindenwold Line has shown a considerably better passenger attraction than Shirley Busway.

ANALYSIS OF PARAMETERS: COMMUNITY

Quality of Service

Overall quality of service from the community's point of view is difficult to evaluate for single facilities. Most of its individual components have been discussed earlier, and therefore the quality of service as such will not be included in the summary comparison.

System Impact

Two major items are included in the discussion of system impact: first, the impact of the transit system on other modes and, second, its long-range impact on land use, city form, etc.

Lindenwold—A survey reported by Vigrass (10) indicated that 40 percent of the line's patrons were previously auto drivers. Since capacity of park-and-ride facilities has been doubled, the percentage could only have increased. If one conservatively assumes that only 37 percent would be using automobiles, that would amount to 7,600 trips per direction per day, or 3,040 during 1 peak hour, when levels of service are extremely sensitive to volumes. In addition to the benefits to other auto users created by this flow reduction, some 7,000 to 8,000 parking spaces are now at outlying stations rather than in high-density central areas of Philadelphia (where 1 space costs $4,000) and Camden. The only negative impact is felt in some areas around the stations (particularly Haddonfield) where traffic congestion has increased considerably in the station vicinity.

Impact on city form can be expected to stimulate strengthening of suburban centers around the stations and vitality of the Philadelphia CBD; both impacts are desirable.

Shirley—The analysis of impact of Shirley Lines is even more complex because of current construction work that impedes traffic. An analysis similar to that for Lindenwold indicates that only approximately 2,000 car trips per day have been diverted to buses. The benefits in terms of traffic volume and parking demand decrease are similar to those for Lindenwold, although at a smaller scale since the number of riders is substantially lower. Because of the extreme dispersal of lines in the suburbs, no impact in terms of formation of subcenters in those areas is expected with the present type of service.

Comparison—With respect to impact on traffic congestion, parking in the CBD, and urban form, Lindenwold is considerably better. On feeder sections Shirley creates less congestion. In total, Lindenwold is better, although impacts of both systems are very positive.

SUMMARY OF COMPARATIVE ANALYSIS

For an easy overview of the foregoing comparison of the 2 systems, their evaluation with respect to each characteristic is described in Table 3 by 1 of 5 terms: very good, good, fair, poor, and very poor. It is emphasized that this evaluation is made with respect to the desirable feature of individual system characteristics. Thus, "very poor" for cost implies that the system cost is very high. Clearly, this type of evaluation is subjective in absolute terms, but its simplicity makes it helpful in comparing the two systems.

Table 2. Operational characteristics and system use.

Characteristics	Lindenwold Line	Shirley Busway	
		All Services	NVTC Only
Weekday hours of operation	19 + 5[a]	6 + 12[a]	6 + 4[a]
Daily trips			
Weekdays	288	789	203
Saturdays	230	200	0
Sundays	156	83	0
Average travel speeds (mph)			
Line-haul	47	35	35
Suburban collection	25 (auto)	N. A.	13 (bus)
Downtown distribution	24	12	12
Overall (typical)	30	N. A.	20
Average speed on competing highway (mph)	12-30	10-20	
Number of vehicles	75	265 (est.)	76
Peak-hour seated and standing passengers per vehicle	76 + 32	49 + 5	47 + 5
Average peak-hour floor area per passenger (square feet)	6.3	5.3	5.7
Vehicle-miles per weekday	13,746	N. A.	8,494
Miles per vehicle per day	183	N. A.	112
Number of passengers per weekday	41,500	24,300	9,270
Average trip length on the system (est. miles)	8.5	N. A.	12.7
Passenger-miles per weekday	353,000	N. A.	118,000
Passenger-miles per vehicle-mile	25.7	N. A.	12.2
Fare (cents)	35-75	40-80	40-80
Revenue per passenger (dollar)	0.57	N. A.	0.70
Operating cost per passenger (dollar)	0.51	N. A.	0.68[b]
Revenue per passenger-mile (dollar)	0.067	N. A.	0.055
Cost per passenger-mile (dollar)	0.060	N. A.	0.053[b]

N.A. = not available.

[a]Hours with very low frequencies.

[b]Includes weekly fee but not diversion cost.

Figure 3. Availability of service: Routes and daily frequencies.

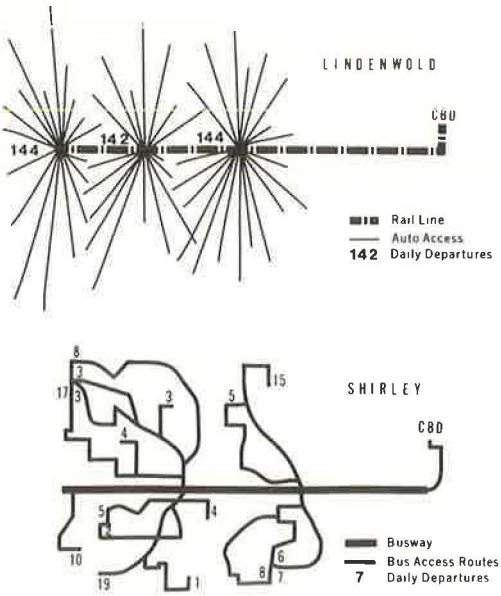


Table 3. Summary of comparative analysis.

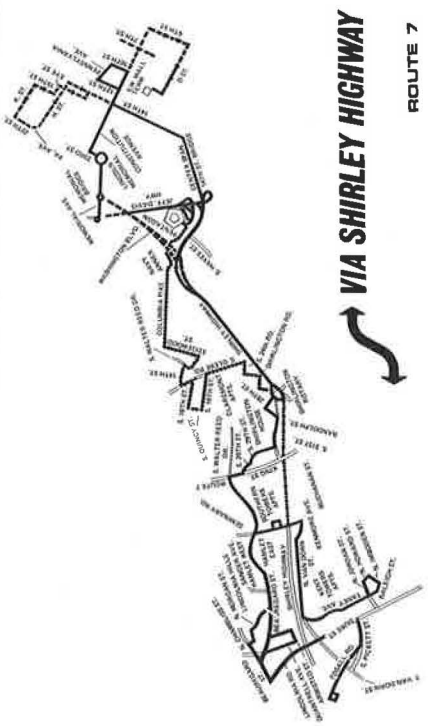
Requirement	Lindenwold	Shirley	Higher Rated System
Passenger			
Availability	Good	Poor	Lindenwold
Speed (travel time):			
Absolute	Very good	Good	Lindenwold
Relative to auto	Good	Very good	Shirley
Reliability	Very good	Poor	Lindenwold
User cost	Good	Very good	Shirley
Comfort	Good	Poor	Lindenwold
Convenience	Good	Fair	Lindenwold
Safety and security	Very good	Good	Lindenwold
Operator			
Area coverage	Good	Very good	Shirley
Frequency	Very good	Very poor	Lindenwold
Speed	Very good	Poor	Lindenwold
Cost: investment	Very poor	Fair	Shirley
Cost: operating	Good	Fair	Lindenwold
Capacity	Good	Poor	Lindenwold
Side effects	Good	Fair	Lindenwold
Passenger attraction	Very good	Good	Lindenwold
Community			
System impact	Very good	Good	Lindenwold

Figure 4. Shirley Route No. 7: Eastbound schedule and route map.

LINCOLNIA–WASHINGTON LINE
EASTBOUND

	ROUTE NO.	SYMBOL	SOUTHPORT APTS.	ORLEANS VILLAGE	DUKE & BEAUREGARD	KENT TOWERS	SHIRLEY DUKE	MORGAN & BEAUREGARD	SOUTHERN TOWERS	BUSWAY AT SEM. RD.	28TH & KING STS.	SHIRLINGTON	BUSWAY AT SHIRLINGTON	PENTAGON	VIA END OF BRIDGE	14TH & CONST. AVE.	WASHINGTON TERMINAL	S.W. MALL TERMINAL	FARRAGUT SQUARE *
A.M.	7D	M	...	...	...	...	...	(Claremont 6:10)			6:13	6:19	6:20	6:25	6:30	6:36	6:38	...	...
	7P		6:00	...	6:10	6:12	...	6:16	6:23	...	6:26	6:36	6:38	6:44	(6:49 Crystal City)			...	...
	7F	M	6:11	...	6:21	6:23	...	6:27	6:34	...	6:38	6:47	6:49	6:55	7:00	7:06	...	7:14	...
	7P		6:19	...	6:29	6:31	...	6:35	6:42	...	6:47	6:55	6:57	7:03	(7:08 Crystal City)			...	...
	7M	H-EX	6:27	...	6:37	...	...	6:40	6:47	6:50	...	...	...	...	6:55	...	...	7:11	...
	7G	H-EX	...	6:35	6:38	...	...	6:42	...	6:51	...	...	...	...	7:00	7:06	...	...	7:15
	7P		6:29	...	6:39	6:41	...	6:46	6:53	...	6:58	7:06	7:08	7:14	...	...	...	...	...
	7E		...	...	...	...	...	(Claremont 6:48)			6:53	7:01	7:03	...	7:09	7:15	...	...	7:24
	7X	M-EX	6:33	...	6:43	6:45	...	6:50	6:57	7:00	...	...	...	...	7:10	7:19	...	7:29	...
	7G	H-EX	...	6:50	6:53	...	...	6:57	...	7:06	...	...	...	...	7:15	7:21	...	...	7:30
	7N		...	...	...	...	...	...	7:01	...	7:06	7:14	7:16	7:22	(7:27 Navy Annex)			...	...
	7E		...	...	...	...	...	...	7:02	...	7:07	7:15	7:17	...	7:23	7:28	...	...	7:39
	7E	M-EX	...	...	...	...	...	(Claremont 7:03)			7:08	7:16	7:18	...	7:25	7:34	...	7:44	...
	7N		6:42	...	6:54	6:56	...	7:01	...	...	7:11	7:19	7:21	(7:27 Navy)	(7:32 Pent.)			...	...
	7Y	SF	...	...	...	...	...	(Claremont 7:13)			7:18	...	7:33	7:38	(7:48 Yes. & Dks.)			...	...
	7X	H-EX	...	...	...	6:57	...	7:02	7:09	7:12	...	...	...	...	7:21	7:27	...	...	7:36
	7P	EX	6:45	...	6:57	6:59	...	7:04	7:11	7:14	...	...	...	7:23	(7:28 Crystal City)			...	...
	7W	M-EX	6:52	...	7:04	...	...	7:09	7:15	7:18	...	...	...	...	7:28	7:37	...	7:47	...
	7M	H-EX	6:54	...	7:06	...	...	7:10	7:17	7:20	...	...	...	...	7:30	...	...	7:41	...
	7G	H-EX	...	7:05	7:08	...	...	7:12	...	7:21	...	...	...	...	7:30	7:36	...	...	7:45
	7W	H-EX	6:55	...	7:08	...	...	7:12	7:18	7:22	...	...	...	...	7:31	7:37	...	...	7:46
	7E	H	...	...	...	...	...	(Claremont 7:17)			7:22	7:30	7:32	...	7:38	7:44	...	...	7:53
	7E	M-EX	...	...	...	...	...	...	7:20	...	7:25	7:33	7:35	...	7:42	7:51	...	8:01	...
	7P	EX	6:55	...	7:07	7:09	...	7:14	7:21	7:24	...	...	...	7:33	(7:38 Crystal City)			...	...
	7P		...	...	...	...	...	...	7:25	...	7:30	7:38	7:40	7:48	...	...	...	...	...
	7W	H-EX	...	...	7:14	...	...	7:18	7:25	7:28	...	...	...	...	7:37	7:43	...	...	7:52
	7E		...	...	...	...	...	...	7:25	...	7:30	7:38	7:40	...	7:46	7:52	...	...	8:01
	7X	M-EX	...	...	...	7:15	...	7:20	7:27	7:30	...	...	...	...	7:40	7:49	...	7:59	...
	7G	H-EX	...	7:15	7:18	...	...	7:22	...	7:31	...	...	...	...	7:40	7:45	...	...	7:55
	7W	H-EX	7:10	...	7:22	...	...	7:26	7:33	7:36	...	...	...	...	7:45	7:51	...	...	8:00
	7G	H-EX	...	7:25	7:28	...	...	7:32	...	7:41	...	...	...	...	7:50	7:56	...	...	8:05
	7E	H	...	...	...	...	...	(Claremont 7:30)			7:35	7:43	7:45	...	7:51	7:57	...	...	8:06
	7E	H	...	...	...	...	...	...	7:32	...	7:37	7:45	7:47	...	7:53	7:59	...	...	8:08
	7P		7:10	...	7:22	7:24	...	7:29	7:36	...	7:41	7:49	7:51	7:57	(8:02 Crystal City)			...	...
	7W	M-EX	7:15	...	7:27	...	...	7:31	7:38	7:41	...	...	...	...	7:51	8:00	...	8:10	...
	7E	M-EX	...	...	...	...	...	...	7:40	...	7:45	7:53	7:55	...	8:02	8:11	...	8:21	...
	7P	EX	...	...	7:29	...	...	7:33	7:40	7:43	...	...	...	7:52	(7:57 Crystal City)			...	...
	7X	H-EX	...	...	...	7:27	...	7:32	7:39	7:42	...	...	...	...	7:51	7:57	...	...	8:06
	7W	H-EX	...	...	7:34	...	...	7:38	7:45	7:48	...	...	...	...	7:57	8:03	...	...	8:12
	7P	EX	...	...	7:37	7:34	...	7:38	7:46	7:49	...	...	...	7:58	(8:03 Crystal City)			...	...
	7M	H-EX	7:24	...	7:36	...	...	7:40	7:47	7:50	...	...	...	...	7:59	...	...	8:11	...
	7E	H	...	...	...	...	...	(Claremont 7:43)			7:48	7:56	7:58	...	8:04	8:10	...	...	8:19
	7P	EX	7:26	...	7:38	7:40	...	7:45	7:52	7:55	...	...	...	8:04	(8:09 Crystal City)			...	...
	7P		...	...	...	...	...	...	7:48	...	7:53	8:01	8:03	8:09	(8:14 Crystal City)			...	...
	7G	H-EX	...	7:35	7:38	...	...	7:42	...	7:51	...	...	...	...	8:00	8:06	...	...	8:15
	7W	H-EX	7:28	...	7:40	...	...	7:44	7:51	7:54	...	...	...	...	8:03	8:09	...	...	8:18
	7X	M-EX	...	...	...	7:37	...	7:42	7:49	7:52	...	...	...	...	8:02	8:11	...	8:21	...
	7E	M-EX	...	...	...	...	...	...	7:51	...	7:56	8:04	8:06	...	8:12	8:21	...	8:31	...
	7X	M-EX	...	...	...	7:43	...	7:48	7:55	7:58	...	...	...	...	8:08	8:17	...	...	8:27
	7W	EX	...	...	7:45	...	...	7:49	7:56	7:59	...	...	...	...	8:08	8:14	...	...	8:23
	7E		...	...	...	...	...	...	7:53	...	7:58	8:06	8:08	...	8:14	8:20	...	...	8:29
	7W	M-EX	7:36	...	7:48	...	...	7:52	7:59	8:02	...	...	...	...	8:12	8:21	...	8:31	...
	7E		...	...	...	...	...	...	8:00	...	8:05	8:13	8:15	...	8:21	8:27	...	...	8:36
	7X	H-EX	...	...	...	7:50	...	7:55	8:02	8:05	...	...	...	...	8:14	8:20	...	...	8:29
	7G	H-EX	...	7:45	7:48	...	...	7:52	...	8:01	...	...	...	...	8:10	8:18	...	...	8:25
	7E	M-EX	...	...	...	...	...	(Claremont 7:55)			8:00	8:09	8:10	...	8:17	8:26	...	8:36	...
	7Y	SF P	...	...	...	...	...	(Claremont 7:58)			8:03	8:20	8:22	8:28	...	...	...	...	...
	7E	H	...	...	...	...	...	...	8:06	...	8:13	8:21	8:23	...	8:29	8:35	...	...	8:44
	7X	H-EX	...	...	...	7:54	...	7:59	8:06	8:09	...	...	...	...	8:18	8:24	...	...	8:33
	7G	H-EX	...	7:55	7:58	...	...	8:02	...	8:11	...	...	...	...	8:20	8:26	...	...	8:35
	7X	M-EX	...	...	...	7:59	...	8:04	8:11	8:14	...	...	...	...	8:24	8:32	...	8:40	...
	7W	M-EX	7:49	...	8:01	...	...	8:05	8:12	8:15	...	...	...	...	8:25	8:33	...	8:41	...
	7X	M-EX	...	...	...	8:04	...	8:09	8:16	8:19	...	...	...	...	8:29	8:37	...	8:45	...
	7G	H-EX	...	8:05	8:08	...	...	8:12	...	8:21	...	...	...	...	8:30	8:36	...	...	8:45
	7E	M-EX	...	...	...	...	...	(Claremont 8:16)			8:21	8:29	8:31	...	8:35	8:46	...	8:54	...
	7G	H-EX	...	8:15	8:18	...	...	8:22	...	8:31	...	...	...	...	8:40	8:46	...	...	8:55
	7B		...	...	...	8:16	...	8:21	...	...	8:30	8:38	8:40	8:46	8:50	8:56	...	...	9:05
	7G	EX	...	8:22	8:25	...	...	8:29	...	8:38	...	...	...	...	8:47	8:53	...	...	9:02
	7G	EX	...	8:32	8:35	...	...	8:39	...	8:48	...	...	...	...	8:57	9:03	...	...	9:12
	7A		8:30	...	8:38	...	...	8:41	...	...	8:49	8:55	...	9:02	9:06	9:13	...	9:21	...
	7G	H-EX	...	8:50	8:53	...	...	8:57	...	9:06	...	...	...	...	9:15	9:21	...	...	9:30
	7F		...	...	...	8:55	...	9:00	9:05	...	9:09	9:15	...	9:22	9:26	9:33	9:35	...	...
	7B		...	...	...	9:16	...	9:21	...	...	9:29	9:35	...	9:42	9:46	9:53	9:55	...	...
	7A		9:30	...	9:38	...	...	9:41	...	...	9:49	9:55	...	10:02	10:06	10:13	10:15	...	...
	7C		...	...	...	...	9:55	...	10:05	...	10:09	10:15	...	10:22	10:26	10:33	10:35	...	...
	7B		...	...	...	10:16	...	10:21	...	...	10:29	10:35	...	10:42	10:46	10:53	10:55	...	...
	7A		10:30	...	10:38	...	...	10:41	...	...	10:49	10:55	...	11:02	11:06	11:13	11:15	...	...
	7C		...	...	...	...	10:55	...	11:05	...	11:09	11:15	...	11:22	11:26	11:33	11:35	...	...
	7B		...	...	...	11:16	...	11:21	...	...	11:29	11:35	...	11:42	11:45	11:53	11:55	...	...
	7A		11:30	...	11:38	...	...	11:41	...	...	11:49	11:55	...	12:02	12:06	12:13	12:15	...	...
	7C		...	...	...	...	11:55	...	12:05	...	12:09	12:15	...	12:22	12:26	12:33	12:35	...	...
	7B		...	...	...	12:16	...	12:21	...	...	12:29	12:35	...	12:42	12:46	12:53	12:55	...	...
	7A		12:30	...	12:38	...	...	12:41	...	...	12:49	12:55	...	1:02	1:06	1:13	1:15	...	...
	7C		...	...	...	...	12:55	...	1:05	...	1:09	1:15	...	1:22	1:26	1:33	1:35	...	...
	7B		...	...	...	1:16	...	1:21	...	...	1:29	1:35	...	1:42	1:46	1:53	1:55	...	...
	7A		1:30	...	1:38	...	...	1:41	...	...	1:49	1:55	...	2:02	2:06	2:13	2:15	...	...
	7C		...	...	...	...	1:55	...	2:05	...	2:09	2:15	...	2:22	2:26	2:33	2:35	...	...
	7B		...	...	...	2:16	...	2:21	...	...	2:29	2:35	...	2:42	2:46	2:53	2:55	...	...
	7A		2:30	...	2:38	...	...	2:41	...	...	2:49	2:56	...	3:02	3:06	3:13	3:15	...	...
	7C		...	...	...	...	2:55	...	3:05	...	3:09	3:15	...	3:22	3:26	3:33	3:35	...	...
	7B		...	...	...	3:16	...	3:21	...	...	3:29	3:35	...	3:42	3:46	3:53	3:55	...	...
	7A	L	3:33	...	3:41	...	...	3:44	...	...	3:52	3:55	...	...	4:07	4:17	...	4:25	...
	7C	L	...	...	...	...	...	...	4:00	...	4:05	4:11	...	...	4:20	4:29	...	4:38	...
	7B	L	...	...	...	4:19	...	4:24	...	...	4:32	4:38	...	...	4:47	4:56	...	5:05	...
	7F		...	...	...	...	...	...	...	...	...	...	...	4:49	4:54	5:03	...	5:12	...
	7A	L	4:30	...	4:38	...	...	4:41	...	...	4:49	4:55	...	5:04	5:13	...	...	5:22	...
	7A		...	...	...	...	...	...	...	...	...	...	...	(23rd & Const. 5:22)			5:28	...	5:37	...
	7F		...	...	...	4:55	...	5:00	...	...	5:09	5:15	...	5:22	5:26	5:35	...	5:44	...
	7B		...	...	...	5:16	...	5:21	...	...	5:29	5:35	...	5:42	5:46	5:55	5:57	...	...
	7A		5:31	...	5:39	...	...	5:42	...	...	5:50	5:56	...	...	6:03	6:10	6:12	...	...
	7F		5:47	...	5:55	5:57	...	6:02	6:07	...	6:11	6:17	...	6:24	6:28	6:35	6:37	...	...
	7A		6:10	...	6:18	...	...	6:21	...	...	6:29	6:34	...	...	6:41	6:48	6:50	...	...
	7F		6:35	...	6:43	6:45	...	6:49	6:53	...	6:57	7:03	...	7:09	7:13	7:20	7:22	...	...
	7Q		...	...	...	...	7:06	...	7:15	...	7:19	7:24	(Navy 7:39)		7:44	7:51	7:53	...	...
	7F		7:35	...	7:43	7:45	...	7:49	7:53	...	7:57	8:02	...	8:09	8:13	8:20	8:22	...	...
	7Q		...	...	...	...	8:06	...	8:15	...	8:19	8:24	(Navy 8:39)		8:44	8:51	8:53	...	...
	7F		8:35	...	8:43	8:45	...	8:49	8:53	...	8:57	9:02	...	9:07	9:13	9:20	9:22	...	...
	7Q		...	...	...	...	9:06	...	9:15	...	9:19	9:24	(Navy 9:39)		9:44	9:51	9:53	...	...
	7F		9:35	...	9:43	9:45	...	9:49	9:53	...	9:57	10:02	...	10:07	10:13	10:20	10:22	...	...
	7Q		...	...	...	...	10:06	...	10:15	...	10:19	10:24	(Navy 10:39)		10:44	10:51	10:53	...	...
	7F		10:35	...	10:43	10:45	...	10:49	10:53	...	10:57	11:02	...	11:07	11:13	11:20	11:22	...	...
	7Q		...	...	...	...	11:06	...	11:16	...	11:19	11:24	(Navy 11:39)		11:44	11:51	11:53	...	...

* Arrive Time 20th & Eye St. Terminal



CONCLUSIONS AND DISCUSSION

Comparison of the Systems

The Lindenwold Line and Shirley Busway serve similar areas and should play virtually identical roles, namely, to connect suburbs with the centers of large cities. However, they differ drastically in the type of service they offer and the results they achieve. The major differences in their services are as follows:

1. Lindenwold, conceived as a system competitive with the auto, provides all-day service. Shirley, conceived as a relief service for high-volume auto movement, provides competitive service mostly during peak hours.
2. Lindenwold provides intensive service—very high frequency at few stations; Shirley's service is extensive—many collection points with low frequencies.
3. Lindenwold, being a rail system, has a very high investment and low operating cost and offers a very high quality of service. Shirley buses require a lower investment and higher operating cost and provide lower service characteristics.
4. Lindenwold relies heavily on auto access (average access distance is 3.2 miles); Shirley relies mostly on walking (84 percent of riders).
5. Lindenwold attracts reasonably good off-peak riding as well as those commuters who would return at different times; such users cannot conveniently use most of the Shirley routes.
6. Lindenwold carries 41,500 weekday trips and operates at capacity during the peaks. With additional cars its capacity could be increased by more than 100 percent. Shirley also operates at capacity, serving 24,300 weekday trips. Its capacity cannot be substantially increased with additional vehicles without decreased speed and reliability of service in the CBD.

Evaluation of Concepts and Modes

The interesting and very important fact is that the two systems, serving similar areas and travel markets, attract different numbers of passengers: Lindenwold carries some 70 percent more daily riders than Shirley. Three factors may be the causes of this advantage:

1. Lindenwold offers all-day service. The reason for this is found in the characteristic of the modes: A single rail line can be operated economically with a much higher frequency than can an extensive network of bus routes.
2. Lindenwold is much simpler to use. This is partly caused by operational deficiencies (e.g., inexcusably complicated information) and partly by the concept: An extensive network is more complicated to use than a single line.
3. Lindenwold offers a considerably higher quality of service. Most of these advantages are related to modal characteristics of rail and bus.

In comparing busway system with rail rapid transit it is concluded that the 2 modes are not fully substitutable: Each has a different optimal domain. The bus mode generally has a lower investment because it does not require an exclusive right-of-way over the entire length of its lines. On the other hand, rail rapid transit has operating cost advantages, mostly because its labor requirement is one-third to one-fifth that of bus service (this ratio increases with passenger volumes). Buses are physically easier to implement but represent a system that is much more difficult to manage and control than rail. Not being physically independent, buses are subject to the influences of many highway authorities, townships, traffic police units, and often several bus company managements.

By utilizing the ability of buses to travel on any highway and street, it is possible to provide an extensive network of routes that permit users to walk to the stops and have a no-transfer ride into the city. However, if this branching out is done to an extreme (Shirley has 127 routing permutations), quality of service seriously suffers. The route layout and quality of service are often more important factors than system costs, since they seriously affect system attractiveness. The systems studied clearly illustrate this point. It is obvious that transferring, objectionable by itself, can be more than

offset by such service aspects as high reliability, frequency, simplicity, and riding comfort (this corroborates the experiences of other cities such as Hamburg). Rail provides these qualities as well as high capacity.

Shirley can be modified to overcome some of these deficiencies by higher frequency and simplicity of service. A major drawback will, however, remain street running in the center city. Bringing an exclusive busway to city streets defeats many advantages of the whole system. To be a high-quality system, a busway must be led into exclusive transit areas in the city center, such as the Lincoln Tunnel-Port Authority Terminal in New York City.

The light rail concept—partially separated rail lines in the suburbs proceeding into tunnels in the city center—falls between the busway and rapid transit concepts and has been very successfully developed in many European cities (11). Light rail requires a considerably smaller investment than rapid transit, offers a quality of service higher than buses, and allows tunnel operation in the city center. It can be incrementally upgraded into a fully controlled system. The system is particularly suited to medium-sized cities.

Needed Improvements to Lindenwold and Shirley

Lindenwold urgently needs to increase its rolling stock, extend the line outward to intercept more of its present and potential riders, and construct additional stations and expanded park-and-rail facilities. These improvements are planned but not yet financed. Eventually, the line should be extended through central Philadelphia and connected with another radial line.

Shirley also badly needs vehicles, but only with considerable improvement of terminal and street operations in central Washington (traffic engineering techniques, enforcement of reserved lane, etc.). However, the most beneficial improvement would be consolidation of suburban routes into fewer and higher frequency lines with adequate information and more hours of high-type operation using the busway. It is specifically suggested that several stations be constructed with ample park-and-ride and kiss-and-ride facilities and with guaranteed all-day service with headways not longer than 10 minutes, and that simple, clear information about the service be provided. This proposal is in line with a similar 1971 DOT recommendation that efforts be made to attract more park-and-ride and kiss-and-ride users to the Shirley Busway. Unless opening of the Metro (subway) line has a major influence on the character of the Shirley system, consideration should also be given to the introduction of articulated buses with considerably greater capacity. These buses are available and are widely used in many European cities.

Some Additional Observations

The relative advantages of one system over the other should not obscure the overall absolute value of either of them. There is a strong consensus among system users and professionals alike that both Lindenwold and Shirley are extremely successful. The fact that both systems attract so many passengers from heavily auto-oriented low-density areas proves that transit need not be an inferior, supplementary mode of transportation: Both systems already carry during peak hours more than 50 percent of all passengers in the corridors in which they operate. A large latent demand for transit has been demonstrated in both cases.

It is absurd that these new systems that have attracted so many new choice riders do not have the funds to provide adequate capacities while numerous parking facilities in centers of both cities are heavily subsidized. It is also a paradox that both systems are basically individual projects rather than parts of major modern transit networks. This clearly shows the need for creation of a much better defined urban transportation policy (including transit, highways, parking, etc.) than our cities now have.

An interesting finding is that the introduction of the Lindenwold Line has resulted in both an increased use of private automobiles as part of the work trip and decreased use of the auto in the center city. Finally, Lindenwold and Shirley show that standard transit modes, bus and rail, are capable of attracting many new riders if they are adequately financed, modern, and well-operated.

In closing, it is pointed out that despite the limitations of this study (complexity of the systems, incomplete data, current changes) it has shown that transportation systems must be analyzed on a comprehensive basis: Qualitative aspects such as comfort, reliability, and information cannot be ignored, even though their evaluation must be partly subjective. Conclusions of this study are relevant to planning of new transit systems, particularly bus and rail modes.

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