Westinghouse ENGINEER

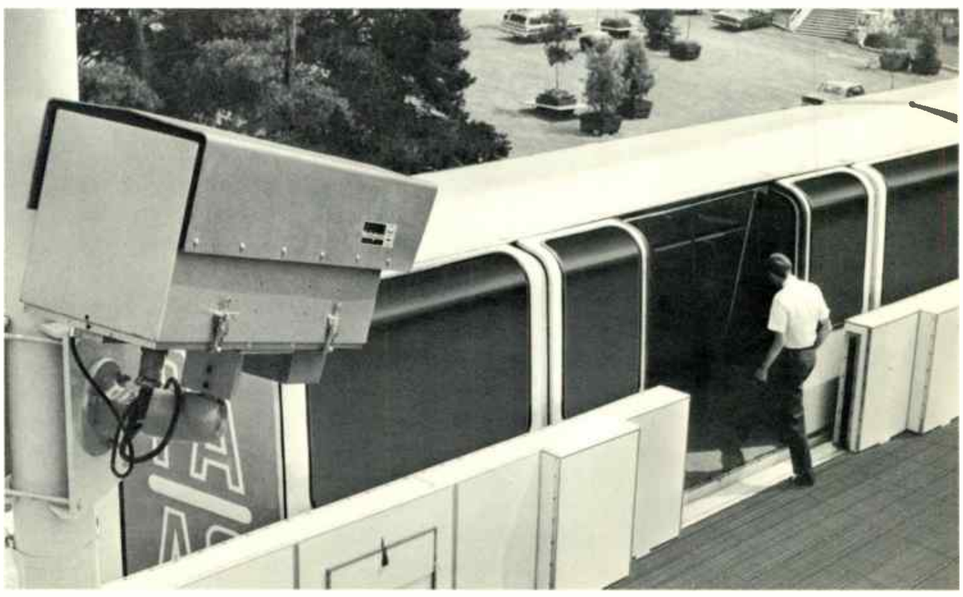
January 1970

Riders on the demonstration line of the Westinghouse Transit Expressway near Pittsburgh, Pennsylvania, participated recently in tests of a television system for monitoring traffic flow and maintaining security at transit stations.

The closed-circuit television system was designed and installed by the Company's Specialty Electronics Division, which expects television to play a major role in transit systems. Its immediate use probably will be at large manned stations for controlling passenger flow and for security purposes, which is the type of installation demonstrated at the Transit Expressway. Later, television systems will be used aboard transit cars, primarily to guarantee the security of passengers but also to insure their comfort by preventing congestion at certain car locations. Moreover, remote unattended stations probably will be monitored for traffic flow and security by television systems connected by microwaves or coaxial cables to control locations.

The system demonstrated was assembled from standard components. Its camera employs a vidicon camera tube and is housed in a weatherproof assembly. It was arranged to observe four key passenger activities: entering the station platform, entering the vehicle, leaving the vehicle, and leaving the platform. A larger transit station would be served simply by using as many cameras as needed to cover the essential traffic areas.

If desired, a transit television system can be equipped with cameras that literally see in the dark by use of SEC (secondary electron conduction) images tubes. Those tubes brighten images hundreds of times, so a station could be fully monitored under moonlight and even starlight conditions.



Westinghouse ENGINEER
January 1970, Volume 30, Number 1

Subscriptions: United States and possessions, $2.50 per year; all other countries, $3.00 per year. Single copies, 50¢ each.

Mailing address: Westinghouse ENGINEER, Gateway Center, Box 2278, Pittsburgh, Pennsylvania 15230.

Published bimonthly by the Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. Printed in the United States by The Lakeside Press, Lancaster, Pennsylvania. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106.

Front cover: When rapid-transit systems are designed to fulfill the transportation needs and desires of people, they can shape and direct the growth of urban areas. Artist Tom Ruddy illustrates the development that can accompany a planned station center on a rapid-transit system. This potential for economic growth and many other aspects of transportation planning for urban areas are discussed in this issue.

Back cover: Forty-eight Westinghouse electric stairways serve the new Madison Square Garden and Pennsylvania Station in New York City. Each stairway is four feet wide, travels 120 feet a minute, and can move 9200 people an hour.

Rapid Transit—A Prescription for Urban Growth

G. W. Jernstedt
J. S. Robinson
R. E. Skorpil

Transportation congestion continues to be one of our most pressing urban problems, and the situation grows progressively worse. Although rapid transit could solve the transportation problem (and help solve many other urban problems), meaningful transit plans are conspicuously lacking for most of our cities. Where systems have been proposed, both the general public and industry are confused about the costs and benefits, and consequently they both have been apathetic. As a result, we continue to allow most of our cities to drift into transportation chaos. Attempts to solve the problem with new freeways have solved little, and they generally cost the taxpayer much more per rush-hour commuter than would a rapid-transit system.

When all costs and benefits are considered, well-conceived rapid-transit systems can return to the community benefits worth many times their cost. Legislators increasingly understand this and are beginning to provide the kind of governmental attention and support that eventually will lead to sensible solutions of urban transportation problems. In fact, the massive federal financial support needed appears to be forthcoming this year. To accelerate such activity, the general public must be given a better understanding of the potential benefits of rapid transit and the increasing costs of not making appropriate use of it.

The first article in this five-part report is a general discussion of the problems of public transportation and the benefits of rapid transit. The following four articles compare the costs of highways versus rapid transit, describe a realistic benefit/cost analysis for determining the real value of rapid transit to the community, suggest optional strategies that can increase the return on a rapid-transit system, and prescribe a multifunctional approach to transit station planning to insure the economic success of the transit system by guaranteeing its usefulness to the public.

Traffic has been strangled in cities for so long that it is virtually impossible to find a suitable description of the situation that has not grown trite with overuse. Yet, urban transportation problems continue to increase, today reaching crisis proportions, threatening the growth and economic vitality of large cities and damaging those segments of the community—business and government—whose interests are best served by an economically viable central city. It is paradoxical that the transportation crisis goes unresolved, because it is one of the few urban problems for which there is technological capability for a solution—and its solution carries the potential for saving the taxpayer vast sums of money.

The answer to traffic strangulation lies in developing *balanced* systems of transportation, including a mix of highways, conventional mass transit (buses and trains), and rapid transit. Unfortunately, transportation facilities other than highways have been almost completely ignored. Although the highway system is a necessary common denominator for all urban transportation in this country, and will remain so for the foreseeable future, highways have practical and economic limitations in solving rush-hour traffic problems of the city. As a result, we have not reached the performance levels of increased personal mobility required in a modern city.

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Rapid transit is no panacea that can replace highways, but there are specific applications where it can perform several necessary functions, create new values, and save the community a considerable amount of money in the process.

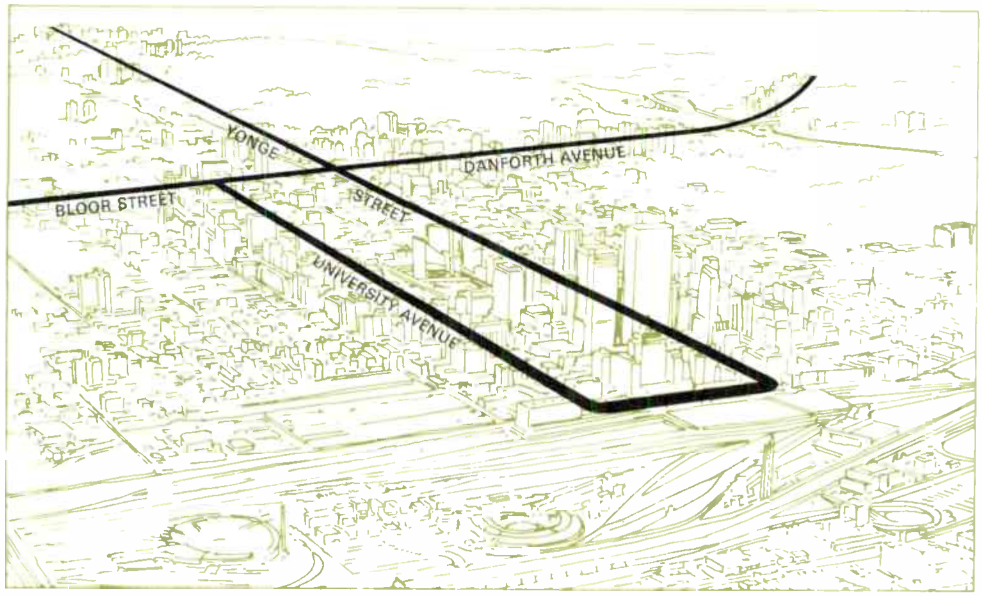
What is Rapid Transit?

Rapid transit is a particular kind of mass transit, generally defined as a method of transporting large numbers of people through the city along well defined corridors, in vehicles operating on private rights-of-way to avoid the traffic snarl of city streets. It can be convenient, fast, reliable, clean, comfortable, and available around the clock—according to design—or it can be otherwise. It can be steel-wheeled, rubber-tired, manual, automatic, operated in trains or in single cars. The possibilities for hardware are almost unlimited and can be whatever is required to achieve any desired level of service in the city. But whatever rapid transit is, *it is not simply another method of transportation.* It is a force that molds and shapes cities. It is an economic stimulus. It is a change in the way of life within a city. It is a profound, dynamic force that has the capability to alter the physical and sociological structure of an entire metropolitan area. Any meaningful discussion of proposed rapid transit systems must consider these many impacts.

Rapid Transit Can Shape Cities

One of the most significant characteristics of rapid transit is its ability to shape and direct the growth of an urban area. It produces two major changes in a city which are stimuli for a host of beneficial secondary effects. First, rapid transit establishes a well-defined corridor of intensified commerce and real estate development. Second, it creates dramatic changes in access to land in the areas affected. These two items feed upon each other. The first stimulates great economic activity adjacent to the rapid transit

Right—The redevelopment that occurs naturally along a high-density transit corridor has been demonstrated in Toronto. The subway routes can almost be located without the color sketch by the high-rise building developments that have grown along the routes.


YONGE
DANFORTH AVENUE
BLOOR STREET
STREET
UNIVERSITY AVENUE

right-of-way because developments that are convenient to good transportation are considered more desirable than those with poor access, and the second significantly adds to the supply of land in the city that is considered attractive for high-rise and commercial development.

The activity that can be precipitated around the rapid transit right-of-way is difficult to imagine if it hasn't been seen. The first short (4.5-mile) subway line constructed in Toronto is an excellent example. When this subway was proposed, critics predicted that such a short stub of a line, running from the heart of the central business district on the south to "nowhere" on the north, would have little effect in a community that has grown predominantly to the east and west. But the critics were wrong.

Toronto's old central business district suddenly sprang to life and stretched northward along the Yonge Street subway in a spurt of magnificent growth. Within a five-year period, over five million square feet of new office space and over eight million square feet of new high-rise apartments sprang up in areas that had been occupied by old single-family dwellings and in a declining central business district. In the first 10 years of its operation, this short stretch of subway attracted over two billion dollars of new construction for every mile of the system. Land values along the right-of-way tripled in two to five years, and at stations went up as much as 10 to 12 times.

The greatly increased number of people working in the area revitalized all forms of commerce in the old central business district as well. The new developments to the north fed secretaries and businessmen into the heart of the central business district, only a five-minute ride away, for lunches, shopping, banking, etc. The subway provided more mobility throughout the greatly expanded central business district than had existed in the old smaller downtown area.

The improvement in mobility was not limited to the Yonge Street area. Traffic patterns changed throughout the city. Although the rush-hour traffic patterns in Toronto are predominantly east-west, commuting time into the downtown area also was unexpectedly improved from these directions because of greater efficiency in the feeder bus systems and reduction of congestion in the central business district streets. Bus-riding commuters can now aim for subway stations on the relatively uncongested fringes of the central business district and ride the subway for the last leg of the journey.

The Toronto subway now includes more than 21 miles of routes, with further additions on the way. The north-south Yonge Street subway has been complemented by an additional short north-south University Line in the central business district, and a major east-west route—the Bloor-Danforth Line.

The city of Toronto presents an example of the *redevelopment* that occurs naturally around the high-density transit corridor, even though no overt attempt is made to use transit for anything more than relieving traffic congestion. The city of Stockholm is a classic example of the use of rapid transit to encourage and direct the orderly *growth* of the city, and in the process, to contribute to an improved way of life for its residents.

Since land in the ancient capitol of Sweden (dating to the 13th century) was essentially all used, city planners felt the need to open *new* land for urban expansion. But in doing so, they wished to avoid disorganized urban sprawl. The satellite city, centered about the transit stop, has met this need. Today Stockholm has 18 satellite cities of from 10,000 to 50,000 inhabitants. A distinguishing feature of these new satellite cities is that despite their distance from the central city (some more than 12 miles), they are not remote and disjointed suburban communities with no tie to the central city. These communities are completely self-contained with fully integrated shopping, residential, commercial, industrial, and educational facilities, yet they are intimately tied to the heart of the old city by a comfortable, convenient subway ride averaging about 15 minutes. Ninety percent of the people travel to downtown Stockholm by the transit system—this despite the fact that Sweden has the world's highest per capita ownership of private automobiles outside of the U.S.

Top—**This high-rise complex has developed around the Eglington station in Toronto. Although it is now the northernmost stop on the Yonge Street subway, an extension will soon stretch the high-speed corridor further north.**

Bottom—**The satellite city of Vallingby is located to the northwest of the central business district of Stockholm. The community is built over and around the subway tracks and stations. Shopping and office space is located at the heart of the center, with apartments and single-family homes surrounding. Behind the center (top of picture) is light industrial and educational facilities in a park-like setting.**

Public Transportation Can Be Pleasant

In addition to public doubts on transportation economics, apprehensions over the comfort and convenience of public transportation have undoubtedly contributed to the apathy for transit proposals. Is rapid transit something people would *ever* desire to use if there were any other way? It definitely can be—if the system is designed with the comfort and convenience of the rider in mind. Unfortunately, most American commuters do not realize that rapid transit in many other countries is a most pleasant way to get around the city. The cities of Toronto, Stockholm, Milan, and others provide examples, all new systems built since 1950. For example, the stations of the Toronto subway are bright, clean, pleasant, thoroughly functional, and even in rush hours, relatively uncrowded. The same can be said for Stockholm, where the subway stations—far from being unpleasant—have become centers for urban and suburban activities. In our own country, some of Boston's rebuilt subway stations demonstrate similar qualities, and special effort is being devoted to make the new BART system in San Francisco attractive and pleasant for its patrons.

Tradition and habit may offer some stumbling blocks to enticing American commuters to use public transit. As a nation of automobile commuters, we tend to equate all public transportation with crowded, dirty subways or buses full of people packed like sardines, standing, hot, and uncomfortable in their smelly conveyance, lumbering along the streets and highways of our cities—while in our automobiles, at least we are relatively comfortable, air-conditioned, seated, and entertained by radios and stereo tapes.

The American automobile commuter who occasionally trespasses into the New York subway system should take comfort knowing that subways around the world are not necessarily thus. In all fairness to the New York system, it must be observed that despite its failings on a human scale, it is the most powerful (and probably the most efficient) transportation machine in the world. The city of New York literally could not exist without it, and it provides an unbelievable degree of mobility within the city at an incredibly low cost. If the New York subway is to be chastised for its crowds, dirt and dinginess, it must be recognized that its shortcomings are based on the same problems that confront almost all other aspects of urban life—lack of money, and how to get a reasonable share of tax revenues back into the cities from whence they came.

Rapid Transit Financing

Despite the overall economic benefits of a well-conceived rapid transit system, few have been built and most major cities that could benefit from them lack any firm construction plans. The difficulty of financing the system has been the greatest deterrent. The traditional reliance on fare-box revenues for financing has been demonstrated to be inadequate. Although some studies have shown that rapid transit lines operating in high-density corridors might be completely self-supporting, experience with comprehensive systems has demonstrated that fares usually cover little more than annual operating and maintenance expenses.

This means, sooner or later, the taxpayer must carry the burden. Local, county and state funds available for this purpose are grossly inadequate and in most cases are capable of little more than the cooperative sponsoring of study projects. It was not until Congress passed the Urban Mass Transportation Act of 1964 that a start on the rapid transit program could be developed and implemented without extraordinary local investments. This Act provides for somewhat limited grants or loans to assist states and local public bodies in the financing of planning studies, demonstration projects, and finally, in the construction of complete mass transportation systems. The maximum share of the cost that the Government will bear is two-thirds of the net project cost—limited to capital costs to avoid federal involvement in operating problems.

Prior to passage of the Mass Transportation Act, local and state funds set aside for transportation projects were used primarily for highway construction, where government subsidies often reach 90 percent of the project cost. With this inequality in federal assistance, a balanced transportation system could not be developed because one key element—rapid transit—seemed to be too expensive.

The two-thirds federal subsidy is dependent upon Congress appropriating the necessary funds, but it is reasonable to expect that these appropriations will be made if a region can provide evidence of a comprehensive plan for balanced regional transportation systems. The remainder of the funds required for rapid transit facilities must be provided by local taxpayers—probably through the issuance of bonds. Traditionally, bonds for this kind of public improvement project would be paid for out of special tax levies, although a number of imaginative approaches have been suggested for future transit bonds. These include localized increased real estate taxes for property adjacent to the transit system, and special resale taxes to be imposed when adjacent property is sold or resold. The proposals are based on the premise that when a rapid transit system sparks a significant rise in land values, the community whose investment made the increase possible should benefit from the increased values. They are an attempt to recapture some of the windfall gains that otherwise would go exclusively to land speculators.

While we are waiting for more realistic federal financing, other means of financing rapid transit offer potential new sources of funds. The state of Massachusetts demonstrated one approach with a new two-cent-per-pack cigarette tax earmarked for public transportation improvements. The city of Baltimore has proposed a ½-percent regional sales tax. Some proposals also have been advanced to increase automobile registration fees and gasoline taxes and to use those funds for a general transportation improvement. However, it is probably unrealistic to expect to do much more with these special taxes than put highways on a sounder financial basis. (The Federal Highway Trust Fund *has* covered the cost of construction of the Interstate Highway System, but this is only half of the total cost of highways when operation and maintenance are considered.)

One assist to the rapid transit problem is the interpretation of the use of the Highway Trust Funds to include the purchase of peripheral parking lots for our urban areas. These will help the motorist get from the highway to the rapid transit system.

The harvesting of land-value increases also offers some possibilities for financing transit investments. Experience in cities where rapid transit has been constructed indicates that peripheral land values increase greatly as a result of their proximity to convenient transportation. In Stockholm, the metropolitan government is deriving substantial revenue from land leases on or about its transit properties—particularly in the satellite cities where local governments have assumed the role of land developer in new areas opened up and made more attractive by the subway. This extreme approach may not be acceptable for applications in the United States but there are opportunities for capturing some value.

Community Benefits of Rapid Transit

Many benefits accrue to the community from new rapid transit investments—some tangible and some intangible. Any meaningful evaluation of transportation investments must take into account the costs and benefits of the proposed system from three distinct points of view: (1) the perspective of the government agency responsible for judicious use of tax revenues to provide *necessary* public services; (2) the value to the individual citizen-commuter in the community, whether he uses the rapid transit system or not; and (3) the general value to the entire community.

Perspectives of the Government Agency—Government agencies of a metropolitan area must weigh the cost of rapid transit against *all* of its tangible regional benefits including potential revenues and savings. In addition to fare-box revenues, a city should evaluate potential savings in highway systems, parking facilities, conventional bus systems, etc., all of which represent investments that can be reduced by a rapid transit system.

And finally, increased or improved urban development can have great value to the central city. A city that elects to grow on the basis of a healthy mix of rapid transit and highways will not be transportation-limited in its growth but will be limited only by judgements on the maximum *desirable* density. This factor has very significant implications for those members of the local community whose interests are best served by a strong, economically vital central city.

Benefits to the Commuter—Ultimately, the reduced tax burden of lower-cost, more-efficient transportation facilities must benefit all taxpayers, but the benefit to the individual commuter is the most significant. Those who presently drive into the central business district only because there is no satisfactory alternative can achieve sizable personal savings, including the generally lower cost per mile of riding rapid transit and substantial savings in parking, in time, in automobile insurance, and even second-car ownership.

The potential savings in time apply to *all* commuters in the area, whether they use the transit system or not. Those who use it during rush hours will save time because it *is* faster. Those who do not use it may be able to save time because of reduced traffic congestion.

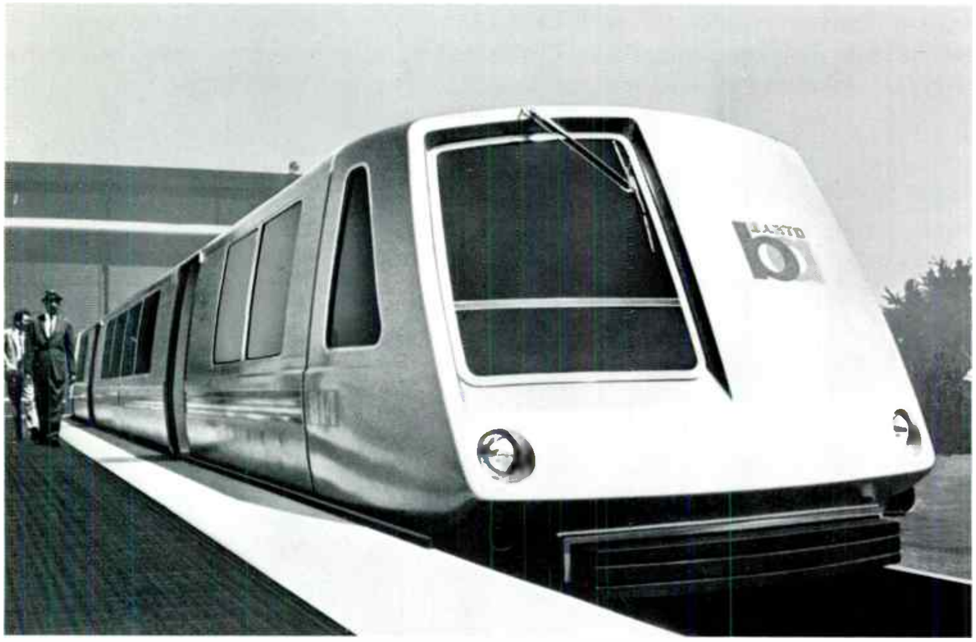
Community Benefits—The less tangible benefits to the community also can be significant. Intuitively, we see that it would be highly desirable for residents of outlying areas of the city to be able to quickly reach central business district shopping areas and other public facilities such as parks, museums, and cultural centers. In a more pragmatic vein, it has been observed that the lack of adequate public transportation contributes to the problems of the urban poor. Workers from this group are most commonly employed in factories and industrial centers, many of which are being moved from the central city to the outlying areas where presently they can be reached only by private automobile. This works an undue financial hardship on the most underprivileged. The long, expensive automobile trip from the suburbs into the central business district may be unpleasant for professional people, but the necessary reverse commuting of the suburban poor to the industrial outskirts of the city can be sheer economic disaster contributing to lower employment, increased welfare expenditures, and other general social and economic problems that plague our cities.

One benefit of rapid transit to the community that can be extremely significant, although difficult to quantify, is the improvement of a city's competitive edge over other cities in attracting new businesses and residents. Any large company attempting to determine where new plants and facilities will be located cannot avoid being influenced by some subjective judgements on the apparent quality of life in the city—whether it seems to be alive, growing and vital, or stagnating. The fact that local business and government leaders are foresighted enough to undertake massive public improvement programs can contribute to the city's competitive advantage.

A fair evaluation of costs and benefits of a proposed transit system must take into account all of these various factors. Only through carefully indentifying all of the costs and benefits to various groups within the urban area, and by informing and educating those groups, can the necessary support be gathered to permit the massive obligations associated with developing a comprehensive big-city transit system.

Organizing to Get the Job Done

If we are to have rapid transit and to realize the community benefits and economies that it affords, the general public *must* be informed about what transit can do for an area, and they must be given the opportunity to choose between all of the desirable transportation alternatives. The key to this is *organization*—the organization of a small but critical number of local business and government leaders who can in turn stimulate the organization of larger efforts to study the rapid transit possibilities for the city and to launch the comprehensive public information campaigns necessary to insure public understanding and acceptance of the financial obligations.



The Bay Area Rapid Transit (BART) system in San Francisco is the first completely new metropolitan rapid transit system in the nation in 60 years. Westinghouse will provide the propulsion equipment and the computerized signalling system that will direct trains.

Solving the transportation problems of our growing urban areas certainly is not going to be easy. It will require the investment of billions of dollars, and this investment must be undertaken quickly if American cities are to grow and prosper in the coming decades. The key is the development of balanced transportation systems within the urban area, with each mode of transportation properly applied —highways, rapid transit, buses, commuter railroads, etc. Failure to recognize the strengths and weaknesses of each of these modes of transportation can cost taxpayers billions of dollars in unnecessary public investments—at a time when many other serious urban problems also cry out for solution.

The situation is particularly urgent because of the long time delays normally associated with the development of working transportation systems (about 20 years for San Francisco's BART). With costs of all goods and services rising daily, large cities can ill afford lengthy gestation periods. In fact, it is probable that they could better afford a number of less-than-ideal transit systems with a few shortcomings, rather than wait for longer-range "optimum" transit systems.

Solving the transportation problem most certainly will not solve all of the city's other problems, but it will beneficially affect a host of them. The key lies in making the taxpayer aware of the relative costs, the possibility of creating new values, and the potential savings to him of an efficient transportation system. If this is to occur, it will be the direct result of inspired local leadership—of the efforts of small handfuls of dedicated men in each city who are willing to take the initiative to get our transportation problems solved. Probably the only alternative is to pour in massive amounts of Federal aid—after the damage has been done to the city. Unfortunately, for the next few years, some Federal aid will be required to rectify the omissions of previous decades. But at the same time, industry and government working together should be able to solve the urban transportation problem on a profitable and permanent basis.

The Costs of Expanding Urban Transportation—Highways versus Rapid Transit

J. S. Robinson
R. E. Skorpil

Rapid transit cannot replace the highway system in the performance of its unique job—even in the crowded central business district where highways are most costly. But rapid transit can supplement the highway system, optimizing public transportation expenditures when certain levels of highway construction costs and rush-hour traffic are reached.

Public transportation in most American cities today is based on accommodation of the automobile. With massive Federal aid, highway and freeway systems are being built or expanded in every major city—and yet these systems are overburdened as soon as they are completed. With an era of even greater urban growth predicted, cities must either find better ways of handling rush-hour commuters or lose much of that potential urban growth to outlying areas.

It should be obvious that there is no panacea to the transportation problem—no *one* best way. The lowest-cost (and most effective) transportation system in a major city consists of a balanced network of highways and rapid transit. The problem, then, is to optimize the combination, to determine when and in what proportion rapid transit should be applied with highways. One approach is to evaluate the relative costs of highways versus rapid transit for moving peak-hour passengers into a city's central business district along high-traffic-density corridors. Obviously, the situation differs with various numbers of commuters.

To start with an example, a single rapid transit line with the capacity of a "standard" Westinghouse Transit Expressway system can carry 21,000 passengers per peak hour.* (This number of passengers is arbitrary. The Transit Expressway concept can be used in systems of various capacities. The number is used because representative costs are already available.)

The Institute of Traffic Engineers specifies that a lane of freeway, filled to capacity with 2,000 automobiles per hour, each carrying 1.5 passengers (compared to about 1.3 passengers per vehicle in many studies), can carry a maximum of 3,000 passengers per lane per hour. Therefore, to handle the same peak-hour commuter load of 21,000 passengers per hour, seven lanes of expressway—each way—are required.

What Are the Costs?

Actual construction costs of urban freeways vary, depending upon land costs and terrain. But in general, the cost of a lane of urban freeway can range from less than $500,000 per mile to over $7 million per mile (see Table I for representative cost figures). Assuming a nominal construction cost, without land, of $750,000 per lane per mile—overall average cost of urban construction with a pro rata share of ramps, bridges, grade separations, etc.—the equivalent of a 14-lane highway would cost $10.5 million per mile to construct. Other studies have shown that a Transit Expressway system with a comparable peak-hour passenger capacity could be built for approximately $5 million per mile without right-of-way (representative cost figures given in Table II). Thus, even before land cost is considered, the capital cost of rapid transit for a high-traffic-density area might be as little as one-half the cost of highway construction.

When land costs are included, this ratio can change dramatically because the land required for the equivalent of a 14-lane highway is about 100 acres per mile, whereas a rapid transit system such as Transit Expressway running at grade and including stations requires only 12 acres per mile. The cost of acquiring and razing developed urban land can range from a low of $50,000 per acre (relatively clear land on the edge of the central city) to more than $1 million per acre.

Where land costs exceed $250,000 per acre, a Transit Expressway system can be built most economically on elevated structures on a narrow right-of-way or over existing traffic arteries. Including structures and additional costs for station land, overhead construction will probably increase the cost of the Transit Expressway system by about $3 million per mile, making the total cost approximately $8 million per mile. Where land costs reach the very high values of the central business district, the Transit Expressway could be built on elevated structures or as a subway. If subway construction is used, the tunneling and other extra construction costs will raise the cost per mile by $12 million, or a total of about $17 million per mile.

Representative costs for 14 lanes of highway and a Transit Expressway system are compared in Table III. As indicated, the ratio of highway to rapid transit costs in the central business district could be as great as 6.5 to 1 for this particular commuter load. Toward the edge of the city, with lower land and construction costs, the highway system could cost about three times more than the Transit Expressway system.

Traffic Densities and Land Costs

The previous example demonstrates the relative costs of highways and rapid transit for *high* traffic densities. For *low* traffic densities, the ratios change dramatically and highways cost less. Thus, the breakeven point on costs for highways and rapid transit is a function of both traffic density and land costs. For example, where land costs average $50,000 per acre and where the maximum expected peak-hour passenger traffic is less than 6,000 per hour, a four-lane highway costing $4.4 million per mile (4 lanes × $1.1 million per lane per mile) would be more economical than a lightly-loaded Transit Expressway system costing over $5 million per mile. Conversely, in the heart of the central business district where land costs might easily reach $1 million per acre, a new four-lane highway to carry 6,000 additional passengers per hour might cost over $30 million per mile—a poor investment compared to a Transit Expressway system having three times the capacity of the highway and half the cost.

This brief comparison of two ends of the cost/traffic spectrum demonstrates the need to consider both highways and rapid transit as solutions for specific transportation problems. In analyzing each application, the capital cost, to the

*William J. Walker and John K. Howell, "Transit Expressway . . . A New Mass-Transit System," *Westinghouse ENGINEER*, July 1965, pp. 98-103.

Above—Traffic jams in one direction and unused lanes in the other typify the rush hour peaks on freeways.

taxpayer, of both highway and rapid transit facilities for varying numbers of rush-hour commuters should be considered. To illustrate these costs, assume four different peak-hour passenger loads: 21,000 commuters per hour; 10,500 per hour; 5,250 per hour; and 2,775 per hour. (Loads below 2,775 per hour need not be considered because this loading is well below the comfortable capacity of a four-lane urban highway and it is assumed that a basic road system in any major corridor will have at least this capacity.) Calculating the capital cost per mile of highway or mile of Transit Expressway and dividing those costs by twice the peak-hour passenger capacity (assuming the total peak-time load to be twice the maximum hourly capacity), the capital costs per peak-time passenger can be determined, as shown in Table IV.

The highway costs *per passenger* shown in Table IV are assumed to be essentially constant for each land cost because the size of the highway can be proportional—at least in discrete steps—for changing commuter loads, whereas the rapid transit cost per passenger varies with passenger loading because capital cost is essentially fixed by the basic cost of track

Table I. Cost of Inner City Freeways

City	*Name of Freeway*	*Average Cost per Lane per Mile**
Boston	Boston Central Artery	$6,700,000**
New York	Prospect Expressway	2,300,000
Pasadena	Pasadena East-West	1,700,000
San Francisco	San Francisco Expressway	2,200,000

*These costs are derived from published overall costs of project divided by miles of construction and number of lanes. Thus they are *average* costs over entire length of roadway, so they can be expected to be higher in or near central business districts and lower in outlying portions.

**Cost of Boston Expressway reflects short central city route only—this cost is probably more representative of true cost through developed central business districts.

Table II. Nominal Cost of Transit Expressway—Capacity 21,000 Passengers per Mile

*Element of Cost**	*Average Cost per Mile*
Basic At-Grade Capital Costs—Excluding Right of Way (tracks, stations, rolling stock, etc.)	$ 5,000,000
At-Grade Land Cost (assume 8 acres at $150,000/acre)	1,200,000
Additional Cost for Elevated Construction (assume cost includes structures and increased land cost for stations)	3,000,000
Subway Cost (additional cost for tunneling and subway stations)	12,000,000

Typical Total Capital Costs per System Mile—Includes All Construction, Land, Stations, and Rolling Stock

Type Construction	*Cost per Mile*
At Grade	$ 6,200,000
Elevated	8,000,000
Subway	17,000,000

*Construction and capital costs based on Transit Expressway Report—Feb. 20, 1967. These basic costs have been inflated substantially over those reported in the Report to allow for increases in construction costs.

***Top*—The Westinghouse Transit Expressway vehicle is electrically powered, about 30 feet long, and seats 28 passengers.**

***Right*—The Transit Expressway is designed to give medium density commuter areas an efficient and convenient transportation system. It was put through a two-year study on a 9,340-foot test loop on a site near Pittsburgh.**


PA
AC

construction, right-of-way, stations, etc. Neither of these assumptions is entirely correct, because the capital cost of a highway system *per passenger* would in all probability rise with decreasing traffic and a reduced number of lanes. This increase would occur because the cost of ramps, lighting, etc. would become a larger percentage of the overall cost of the smaller highway. Conversely, there could be reductions in the capital cost of a rapid transit system if lower capacities were anticipated. If we assume these costs to be constant, the analysis is conservative in favor of the highway system, but it permits an examination of the dynamics of changing costs and changing loads.

With the range of values shown in Table IV, the capital costs per passenger-mile of highways and rapid transit can be plotted as a function of traffic as shown in Fig. 1. The cost curves intersect at about 4,900 commuters per hour. Thus, for *this particular set* of transit and highway cost parameters, peak-hour commuter loads of 5,000 or fewer passengers could be handled more economically with highways. If peak-hour passenger loads are expected to rise above the 5,000 level, the rapid transit system would seem to be the more economical system.

This representative application indicates that when rapid transit systems are applied in high-density corridors, they can provide substantial savings to the taxpayer, with costs ranging from about one-third to one-sixth the cost of highways. However, applying rapid transit in low-density corridors is not necessarily an "improper" application if the purpose of the transit system is to help develop new areas in the metropolitan area—as is done in some European cities.

A family of cost curves like the one in Fig. 1, using the number of commuters as the independent parameter, illustrates the capital-cost break-even point for highways and rapid transit as a function of the number of commuters. These values can be plotted (Fig. 2) to provide a pictorial representation of the proper applications for highways and rapid transit.

Thus, at the low end of the highway construction cost scale, a very large number of peak-hour passengers are required to justify a rapid transit expenditure—at least on the basis of first cost per passenger—and a highway system is usually more economical. But as the highway system enters the central city, where highway costs rise, anything more than a "basic" highway system could be very costly to the taxpayers, requiring *additional* public investments of from $600 to over $2,000 per rush-hour commuter for each mile of construction, over and above the investment required for rapid transit.

Other Economic Considerations

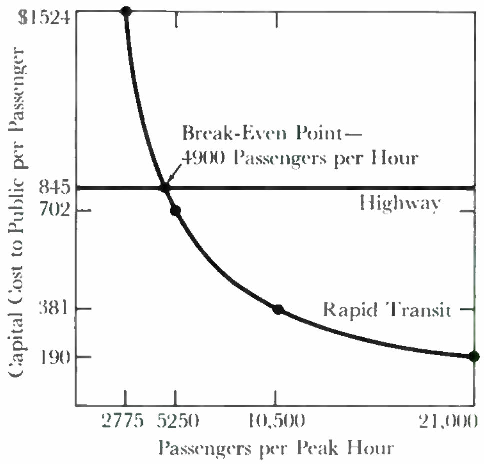
As dramatic as these cost comparisons are, they do not begin to tell the complete story of potential cost. For example, if there is room for considerable future growth in or near the central business district, the capital cost savings in the rapid transit system can be complemented by dramatic additional tax revenues derived from developments on land that otherwise might have been required for highway construction. From the cited example, the additional land for highways to carry 21,000 commuters per hour was assumed to consume an additional 100 acres of valuable city land for each equivalent mile of highway construction. In a Manhattan-style development, 100 acres could accommodate 40,000 additional workers and 12,100 additional permanent residents, which would represent a significant potential for investment and tax revenue. These quantities are listed in Table V. The present worth of the representative tax revenues could amount to over $140 million for each mile of highway not required because of capacity provided by rapid transit. Obviously, this represents an upper limit, but it is not an unreasonable target if our cities grow dramatically in the next few decades. The total benefit to the community in savings of out-of-pocket expenditures for highway construction, plus potential increased tax revenues, might

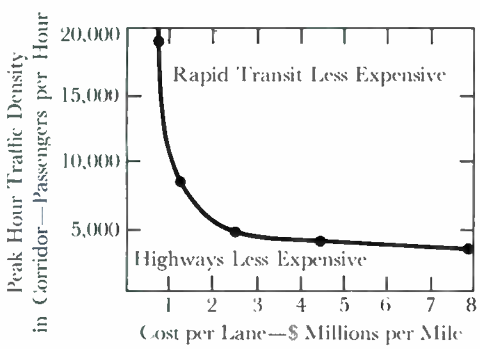
Table III. Capital Cost per Mile of Highways and Transit Expressway to Accomodate 21,000 Passengers per Hour

Land Cost per Acre	*Highways (14 Lanes)*		*Transit Expressway*		*Cost Ratio: Highway / Transit Expressway*
	Cost per Lane per Mile	*Total Highway Cost per Mile*	*Construction Method*	*Cost per Mile*	
$ 50,000	$1,100,000	$ 15,500,000	At Grade	$ 5,600,000	2.8
100,000	1,460,000	20,500,000	At Grade	6,200,000	3.3
250,000	2,500,000	35,500,000*	Elevated	8,000,000*	4.5
500,000	4,300,000	60,500,000	Elevated	11,000,000	5.5
1,000,000	7,850,000	110,500,000	Subway	17,000,000	6.5

*Sample Calculation: (Assume urban highway construction cost, less land, to average $750,000/lane/mile.)

Highway Cost: 14 lanes × $750,000 =	$10,500,000	Transit Expressway Cost: Basic Cost	$5,000,000
100 acres land at $250,000/acre =	25,000,000	Land (or land plus structures)	3,000,000
	$35,500,000		$8,000,000





1—Capital cost per peak-time passenger is shown as a function of passenger volume. (Highways assumed to cost $2.5 million per lane per mile; 21,000-passenger-per-hour rapid transit system assumed to cost $8 million per mile for two tracks.)

2—The relative cost of rapid transit and highways is a function of highway construction costs and rush-hour passengers. (This represents assumed costs of only one rapid transit system design; the relationships could change significantly with different system configurations and passenger capacities.)

Table IV. Capital Costs per Peak-Time Passenger

	Commuters per Hour	*Capital Cost per Passenger per Mile*	
		Highways	*Transit Expressway*
Land Cost: $50,000/acre	21,000	$ 369	$ 133
Highway Cost: $1,100,000/lane/mile	10,500	369	266
	5,250	369	532
(break-even point: 8,500 commuters/hour)	2,775	369	1,064
Land Cost: $250,000/acre	21,000	$ 845	$ 190
Highway Cost: $2,500,000/lane/mile	10,500	845	381
	5,250	845	762
(break-even point: 4,900 commuters/hour)	2,775	845	1,524
Land Cost: $500,000/acre	21,000	$1,440	$ 262
Highway Cost: $4,300,000/lane/mile	10,500	1,440	524
	5,250	1,440	1,048
(break-even point: 4,060 commuters/hour)	2,775	1,440	2,096
Land Cost: $1,000,000/acre	21,000	$2,630	$ 405
Highway Cost: $7,900,000/lane/mile	10,500	2,630	809
	5,250	2,630	1,618
(break-even point: 3,575 commuters/hour)	2,775	2,630	3,236

Table V. Additional Urban Development Possible in 100 Acres of "Manhattan Style" Central Business District

Additional Office Space (200 sq ft/worker)	8,000,000 sq ft	
Value of Office Space ($30/sq ft)		$240,000,000
Additional Permanent Residents	12,100	
Additional Workers	40,000	
Additional Dwelling Units (one for each four permanent residents and commuters)	13,025	
Value of Dwelling Units ($20,000 each)		260,000,000
Total Value of Real Estate (office plus dwelling units)		$500,000,000
Value of City Real Estate Taxes per Year (1 percent of value)		$ 5,000,000
Value of Additional Wage Taxes (assume $100/worker)		4,000,000
Total Annual Taxes		$ 9,000,000
Present Worth of Taxes (30 years, 4 percent)		$146,360,000
Savings in 14-Lane Highway Not Built (assume land at $1,000,000/acre and construction cost at $750,000/lane/mile)		110,500,000
Total Cost in Lost Taxes and Highway Construction		$256,860,000
Rapid Transit Cost per Mile		$ 17,000,000
Benefit-to-Cost Ratio of Rapid Transit	15 to 1	

rise to over $250 million per mile for each equivalent mile of highway capacity. In this case, a 21,000-passenger Transit Expressway system costing $17 million per mile could provide a potential benefit-to-cost ratio of 15 to 1!

Naturally, in any actual situation, these figures must be tempered by the time required for the area to be developed. But the magnitude of the economic factors that can enter into a comparison of rapid transit versus highways for the central business district is significant. It is worth noting that the office and residential construction figures listed for one mile of highway represent the magnitude of growth that occurred adjacent to the Yonge Street subway in the city of Toronto in a period of little more than five years from the opening of the first 4.5-mile leg of the subway system. The conspicuous absence of vast new highways feeding into the central business district of Toronto is living proof of the power of rapid transit to take such urban expansion in stride and to conserve precious inner-city land for additional tax-revenue developments.

This analysis has considered the cost relationships for highways and just one particular rapid transit system. Actually, there are many potential applications for other kinds of systems with different capacities and costs. In fact, we are just on the threshhold of many exciting and imaginative applications of new special-purpose transportation systems. The important consideration for now and the future must be to insure that the costs of *alternate* transportation methods in the city are realistically evaluated so that transportation investments—highways or rapid transit—represent judicious use of public funds and not uneconomical reliance on inadequate traditional approaches.

The Fort Pitt Bridge approach from downtown Pittsburgh demonstrates the loss of valuable central city land to highway construction and related parking.

The Value of Rapid Transit—A General Benefit/Cost Comparison

J. S. Robinson
R. E. Skorpil

A comprehensive benefit/cost analysis demonstrates that an investment in a well-conceived rapid transit system can return to the community benefits that exceed system cost. The return may readily be several hundred percent, depending on the investment.

The impact of rapid transit can be evaluated in terms of its benefits and its costs. Quantifiable benefits are compared with estimated costs to determine the percent of total costs offset by the benefits. To account for the time element—because benefits and costs may be spread over long periods of time—a present-worth analysis is applied to all incomes and expenditures, thus providing a useful evaluation of the various investment choices. This evaluation permits decisions to be based on a careful analysis of expected returns on public money.

Intangible benefits that cannot be quantified and used directly in the analysis ("Rapid Transit—A Prescription for Urban Growth," p. 2) should be included in the final review and determination of the desirability of the transit investment.

The tangible benefits that result from a rapid transit system may be grouped in various ways for evaluation. One logical approach is to group them on the basis of two special interest groups—the government agency that must make the investment of public funds and the commuters who live in the area.

Benefits to Public Agencies

The first grouping, which might be considered *primary benefits*, is defined as benefits that accrue to the public agency making the transit investment. This public agency, as an agent of municipal government, benefits from, and is charged for, all transportation-related items in the greater metropolitan area. Therefore, all measurable transportation costs, benefits, and revenues that affect the local government complex are included.

By definition, funds that would have been spent to provide needed transportation facilities in the city *but are not required if rapid transit is available* are termed "benefits"; funds expended for transportation with a rapid transit system are called "costs." When benefits are weighed against costs on a present-worth basis, the return on investment can be calculated.

The primary benefits from rapid transit that result from *not having to invest* public funds in other modes of transportation include:

Conventional Bus Systems—Diversion of bus riders to rapid transit allows a considerable decrease in capital, operating, maintenance, and replacement costs for bus facilities that would otherwise be required to serve these riders.

Table 1. Primary Benefits to the Transit Authority of Baltimore Over a 50-Year Period

	Annual Value (millions $)	*Total Present Worth (millions $)*
Savings in investments not made for other transportation modes:		
Bus system: Diversion of 300,000 riders/day by 1985 will decrease capital, operating, maintenance, and replacement costs. (Based on 6¢/passenger mile, fare income subtracted.)	$16.6	$ 356.0
Freeway system: Additional highways required without transit. (Based on costs of $19 million/mile.)		380.0
Feeder streets: Secondary feeder streets required without transit. (Based on costs of $3 million/mile.)		144.0
Operation, maintenance, and repair of additional freeway and feeder streets (at 2 percent of initial capital costs).	10.5	225.1
Unincurred property tax losses:		
Real estate taxes lost to additionally required land for freeways, feeder streets, and parking lots. (Based on $148 million in lost assessed valuation.)	$ 5.6	$ 120.6
Land freed by rapid transit for higher use and increased valuation. (Based on 19,000 cars × 300 sq ft/space × 50¢ = $0.7 million assessed valuation for tax gain.)	0.026	0.6
Tax revenues from improvements around stations. (Net increase in valuations, estimated at 25 percent of the total increase.)		$ 106.6
Total primary benefits		$1,332.9
Estimated total capital cost of rapid transit system.		$1,719.5
Primary return on total investment ($1,332.9 ÷ $1,719.5).	77.5%	

Transit revenue from fares and annual operating cost have not been included, assuming the two items will cancel each other on an annual basis.

Freeway Systems—In the absence of rapid transit, additional high-speed high-volume freeway systems would be required. Therefore, savings that accrue with rapid transit can be based on the highway construction costs saved.

Feeder Streets—Without rapid transit and with an expanded freeway system, a substantial number of secondary feeder streets would also have to be constructed. Also, the expenses of operation, maintenance, repair of the additional freeways and feeder streets can be avoided with a transit system.

Another primary benefit to the public agency is the *unincurred property tax loss.* Without rapid transit, the additional freeways, surface feeder streets, and parking lots required will eliminate a substantial amount of real estate value from the tax rolls. With rapid transit, valuable land that would have been required for parking can be used much more effectively, which will ultimately *increase* its assessed evaluation.

Transit-related revenues to the public agency include fare-box revenues and tax revenues from real estate improvement around stations. The most conservative approach assumes that the fare box will provide only the annual operating and maintenance costs of the system. Actually, in some cases the fare box may make a contribution to recovery of capital costs. The experience of existing transit systems has demonstrated that substantial commercial developments occur around transit stops, property values rise accordingly, and the increased property evaluations bring in additional tax revenues. Net assessed evaluation, with its resultant tax gain, is the real benefit here, calculated from the total increase in assessed evaluation expected around the stations.

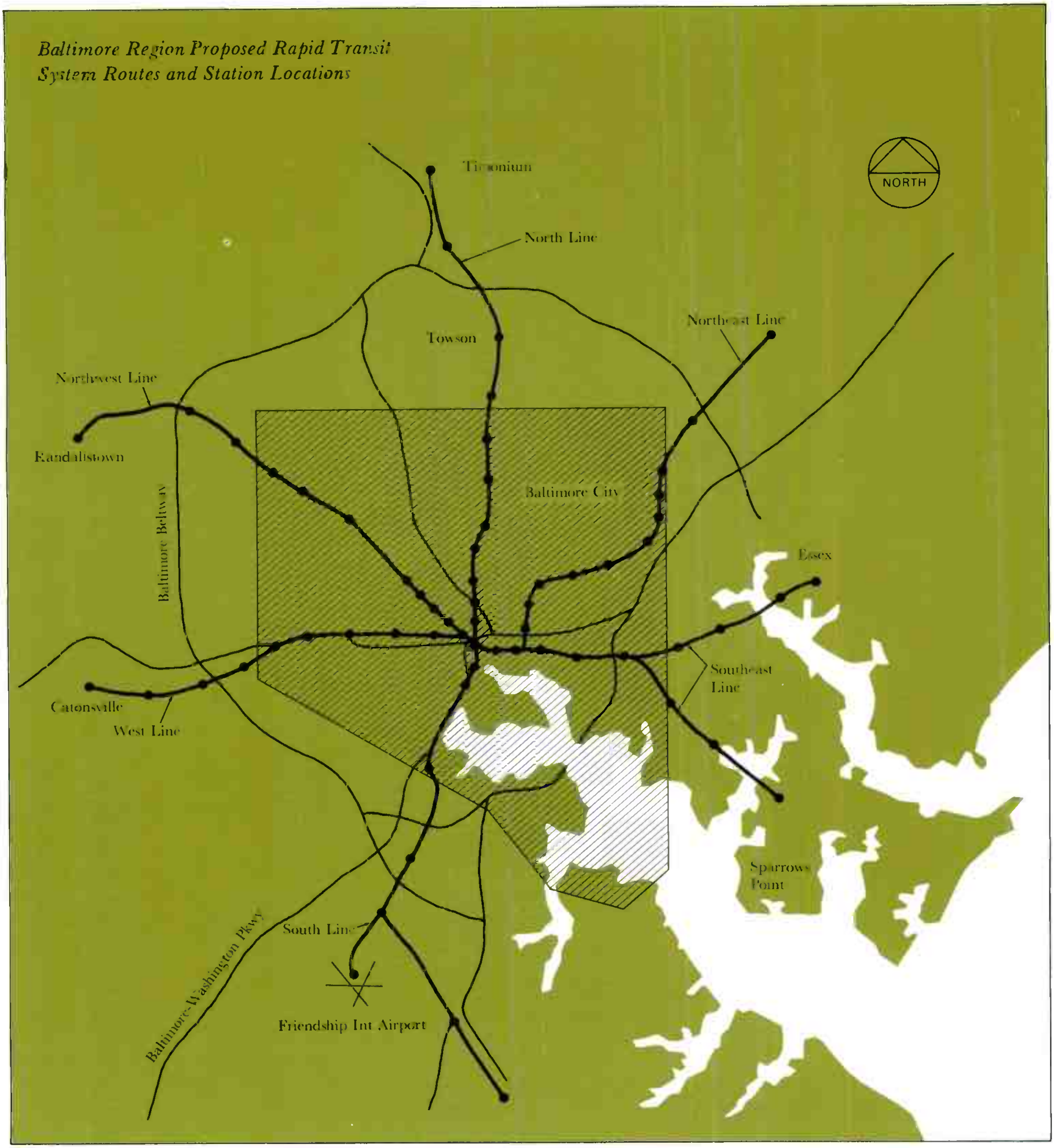
Benefits to Commuters

The potential *secondary benefits* (direct benefits to commuters in the urban area) are many. They include reduction in auto operating expenses, reduction in bus fares, reduction in downtown parking fees, savings in car insurance premiums by eliminating commuting as an element in yearly driving costs, reduced cost of auto ownership (second and third cars no longer needed in some households), and the value of time saved in commuting.

Table II. Secondary Benefits to Commuters in the Baltimore Area Over a 50-Year Period

	Annual (millions $)	Total Present Worth (millions $)
Benefits to transit users:		
Reduced auto operating expense (59,000 drivers diverted to rapid transit daily)	$19.6	$421.9
Savings in bus fares (300,000 riders diverted to rapid transit)	36.0	773.0
Reduction in downtown parking fees (19,000 at $300/year)	5.7	121.2
Reduced cost of auto ownership (estimated reduced need for 6,000 second and third cars no longer needed in some households)	6.2	132.2
Benefits to non-users:		
Vehicle operating costs saved by decreased traffic congestion (55,000 cars save 9,100 hours annually)	$4.2	$91.8
Reduced vehicle operating cost for trucking industry (one minute saving for each of 682,000 light truck trips)	4.7	101.6
Benefits for the unemployed (estimated)	1.6	34.4
Total secondary benefits		$1,696.1
Less cost of benefits (transit fares)		−967.0
Net secondary benefits		$ 729.1
Estimated total capital cost of transit system		$1,719.5
Net secondary return on total investment ($729.1 ÷ $1,719.5)	42.4%	
Time savings due to reduced commuting time:*		
Transit users		$287.6
Non-users		75.5
		$363.1
Return on investment including time saved ($729.1 + $363.1) ÷ $1,719.5	64%	

*The value of individual time savings has been separated from other secondary benefits because of the controversial nature of this item. In Baltimore, time savings were valued at 47 cents/hour, the average contribution of each person to the Gross National Product. In San Francisco, they were valued at more than $3/hour, but many consultants are reluctant to attach any value at all.



Baltimore Region Proposed Rapid Transit System Routes and Station Locations

The benefits to non-users of rapid transit include reduction in vehicle operating costs brought about by less time spent in commuting (a result of decreased traffic congestion), reduced vehicle operating costs for the trucking industry resulting from relieved traffic congestion, and the value to the individual of personal time saved in commuting.

Benefits to the unemployed fall in the category of social improvements and are generally considered to be intangible benefits because of the difficulty in quantifying them. However, the connection between unemployment and lack of mobility is so substantial that an improvement in access to jobs via rapid transit should be related to increased wages for the region's unemployed.

The Baltimore Benefit/Cost Analysis

For a discussion of the value of a rapid transit investment to have real meaning, the benefits must take on dollar values so that comprehensive comparisons with costs can be made. Assigning specific dollar values that could be applicable to all regions is impossible; however, we can examine one region to illustrate the order of magnitude of potential benefits.

In the fall of 1968, the Mass Transit Steering Committee of the Regional Planning Council of Baltimore, Maryland, released a "Feasibility and Preliminary Engineering" study on a proposed total transportation system for that city. The overall approach of both the city of Baltimore and the state of Maryland emphasized the need for comprehensive evaluations of the full range of regional benefits that might result from rapid transit. The report, prepared with financial aid from the U.S. Department of Housing & Urban Development, promises to be the archetype of future rapid transit evaluation studies. Major topics discussed in the Baltimore report include transportation planning, evaluations of new technology, patronage and revenue projections, preliminary engineering, and impact studies. However, the Baltimore results, as presented here, do differ slightly from the analysis given in Baltimore's report because costs and benefits have been regrouped to be consistent with our definitions of *primary* benefits in the conservation of public funds, and *secondary benefits* to the area commuters.

A second difference in the analyses results from the variation in the methods used to deal with operating and maintenance costs. In the Baltimore study, these items were added to capital costs and the resultant total weighed against gross revenues to calculate return on investment. In our study, operating and maintenance costs are subtracted from gross revenues to obtain a net revenue figure. This is compared to initial capital costs and return on investment calculated.

The primary and secondary benefits, derived from Baltimore's figures, are listed in Tables I and II. These represent the present worth of costs and benefits based on an assumed 50-year life span of the project and a four-percent present-worth discount factor. These primary and secondary benefits for Baltimore are summarized in Table III. The comparison demonstrates a return on overall investment of 119.9 percent excluding the value of time savings, and 141 percent when time savings are included. Expressed as return on local investment with credit taken for federal subsidies, the potential returns are seen to be approximately 360 percent excluding commuting time savings, or 423 percent including them.

Table III. Summary—Baltimore Benefit/Cost Analysis

	Present Worth (millions $)	*Percent of Total System Cost*
Primary Benefits	$1,332.9	77.5
Secondary Benefits (net)	729.1	42.4
Total Quantifiable Community Benefits	$2,062.0	119.9%
Time Savings	363.1	21.0
Total	$2,425.1	140.9%
Total Estimated System Cost	$1,719.5	
Return on Investment:		
Excluding time savings		$\frac{2,062.0}{1,719.5}=119.9\%$
Including time savings		$\frac{2,425.1}{1,719.5}=140.9\%$
Local Investment 1/3 ($1,719.5)=$573.2 (Total investment minus federal subsidy of 2/3 project costs)		
Return on Local Investment:		
Excluding time savings		$\frac{2,062.0}{573.2}=359.7\%$
Including time savings		$\frac{2,425.1}{573.2}=423\%$

The extremely conservative nature of all of the Baltimore analysis should mollify critics of the proposed system. Close scrutiny of the numbers makes it difficult to understand how the benefits could possibly be this low. For example, the Baltimore study takes credit for less than $1 billion of additional construction presumed to occur over the 50-year time span. This is considerably less than the amount of new construction that actually did occur in Toronto in less than five years. However, Baltimore's conservatism is understandable and can be expected to prevail in other studies until greater experience with rapid transit projects in this country gives planners a firmer base for projecting benefits. The significant fact is that the Baltimore study represents a landmark in the development of officially recognized methods of justifying rapid transit on the basis of overall community benefits, and not simply on the basis of expected fare-box revenues.

Optional Strategies for Increasing the Return on Transit Investment

J. S. Robinson
R. E. Skorpil

The increases in land value created by rapid transit facilities provide potential sources of revenue for public transit agencies in addition to the primary benefits that result from not having to invest public funds in other modes of transportation.

The tangible economic worth of an investment in rapid transit can be more than just the *primary benefits* to public agencies that invest public funds and the *secondary benefits* to area commuters. Other optional strategies can bring additional benefits for the community. The present worth of benefits derived from these optional strategies can vary from a few percent of the capital cost of the system to possibly more than 100 percent

Unlike the primary and secondary benefits discussed in the previous article ("The Value of Rapid Transit—A General Benefit/Cost Comparison"), positive steps must be taken to capture the revenues from optional strategies. Additional investment may be required to extract added return from the initial transit investment which, in the past, has been unrecoverable by the public sector. At the very least, some governmental action may be required to enable these optional strategies to be used, because they may involve granting the right of excess condemnation to the transit authority, allowing it special tax revenue considerations, or allowing it to assume the role of a land developer.

If rapid transit is already inherently a bargain, why bother with additional strategies, some of which may be politically controversial? The answer must come from local judgements, but typical motives for exercising optional strategies might include:

1) A desire to maximize return on public expenditures to provide additional revenues for other public purposes and provide relief on general tax burdens;

2) A public desire to set up a *self-sufficient* public transit agency that could utilize optional revenues to partially or entirely finance itself without need of additional support from general municipal funds (the primary and secondary benefits would still accrue to the municipal government in the region);

3) A desire to make municipal bond issues more attractive to investors by including a well-planned program to provide future streams of income to the municipality. This also might improve acceptance by the local taxpayers who must approve the bond issues.

Land Value Increases—A Potential Source of Benefit

Transit studies have shown that one impact of major importance is the transit-induced development of real estate occurring in areas adjacent to transit stations. As experienced by Toronto and other cities, demand for land near rapid transit stops is great, and results in sharp increases in land values. In the case of Toronto, land values around the stations have increased 300 to 400 percent (or more) within five years of the construction of the transit system. In the past, quick-acting speculators and developers have capitalized on this appreciation of land value, realizing enormous profits through prudent land purchase and resale. The capture strategies presented here, related to increases in land value, represent possible ways for the *community* to receive greater benefit from these gains.

Potential Capture Strategies

Five major strategies could be employed to capture a segment of the incremental real-estate-related values produced by public investments in rapid transit:

Sale or Lease of Air Rights—Incomes derived from the sale or lease of air rights over transit properties are particularly attractive because no additional investment is required. The land purchased for transit stations or other necessary functions can be considered a "sunk" cost as far as air-right schemes are concerned. Even with the additional cost of constructing an elevated structure, air rights can be much in demand because of direct access to transit facilities. Such construction is a way of life in Stockholm, and this demand also has been experienced in Toronto where several structures already have been built over stations.

Generally, the sale of air rights should be made *after* high land values have become established in the areas near transit stations. Experience in Toronto shows that close cooperation between the transit authority and local zoning authorities can accentuate this benefit, if zoning can be made to help concentrate major development around transit facilities.

Sale of Extra Transit Land—There are two potential sources of "extra" land for resale: the first is obtained by necessity when larger-than-required parcels must be purchased for rights-of-way and stations; the second is land originally intended for future transit facilities but later found to be unnecessary or uneconomical for its intended use. An example of this might be found in parking grounds for park-and-ride facilities. At an early stage, when land is relatively inexpensive, large areas surrounding stations may be purchased for parking needs. When property values increase, parking can be concentrated in multiple-level structures and the balance of the land sold profitably on the open market, or leased on long-term contracts.

Sharing Transit Rights-of-Way—Rapid transit systems quite naturally radiate from the downtown central area to the suburbs. Utility companies may find that many of their service rights-of-way need similar routes. Although utilities may properly exercise their rights of condemnation to acquire needed rights-of-way, sharing transit rights-of-way may offer a better solution. Depending on the transit system and the type of utility construction, it may be possible to share rights-of-way with rental charges that would provide additional income to the transit group and cost savings to the utility. This concept also has favor with urban planners who feel that providing the vital utility services to the city in well defined, coordinated "utility corridors" could help to improve the general environment in the urban area.

Excess Condemnation—This strategy is controversial but has the greatest potential for generating additional revenue. Excess condemnation as applied to transit operations would require the condemnation of key land parcels in the vicinity of proposed transit stations. This land could be developed by the transit agency for high-rise residential or commercial developments, or it could be leased or resold so that others could undertake such uses. The original purchase price would be based on the value of land without transit; the ultimate sale price would reflect the value added by transit.

The states differ in their condemnation laws, and, in many cases, amendments may be necessary to permit this capture strategy to be used. But a soundly conceived program of land purchase and resale could provide substantial future cash flow and could add appeal to transit bonds, both to the investing community and the taxpaying public.

The degree to which excess condemnation is employed could vary considerably. At a minimum, small plots could accommodate individual apartment or office buildings. On extensive tracts, shopping centers or industrial parks might be constructed; in certain instances where growth patterns permit, satellite cities might even be developed.

Special Proximity Taxes—This strategy, while not specifically discussed or quantified, may offer great potential for capturing some gain on increased land values adjacent to the transit stop without putting the public agency into the land-developing business. It involves taxing land near the transit right-of-way or stations at a special higher rate (higher than comparable land in remote parts of the city). These special taxes are applied only when land is sold and/or converted from one use to another higher-density use. The windfall gains on land value increases remain primarily in the private sector, but the public is able to recapture some part of the increased land value created by public investment.

Taxes of this type have some precedent in Great Britain, although they have not been used (as far as is known) in the United States. The practice of applying special taxes only at the time of change of the use of land protects the individual property owner in areas where land use has remained stable; however, it takes into account the increased value of the land when it is converted to high-rise application. Care must be used to apply these special taxes judiciously, because if carried to extremes, they would effectively discourage the very development sought for the area.

Capture Strategies Applied to the Pittsburgh Ohio River Line

To evaluate the order of magnitude of the benefits that might be realized through the use of optional strategies, a number of sample cases were analyzed. They considered hypothetical transit/real-estate developments in Pittsburgh, Pennsylvania, and in Cleveland, Ohio.*

These examples demonstrated that, depending on the number of optional strategies employed and local conditions, the additional value to the community could range from a few percent to over 100 percent of the basic transit investment. The benefits would accrue in addition to the conventional benefits discussed in the other articles in this issue.

One of these sample cases is summarized here. It is a hypothetical Ohio River Line in Pittsburgh. The specific benefits derived are based on available data from the urban region, such as present land values in the area being analyzed.

The capture strategies illustrated are based on a set of assumptions about the nature of the public agency making the investment in rapid transit. First, it is assumed that there are no legal limits on the powers of the agency to use the various applicable capture strategies. The land operations (excess condemnation, selling of air rights, etc.) are assumed to be lawful actions of the public agency. Furthermore, this agency is considered to be a part of the exclusive municipal government. This assumption implies that all revenues are relevant to the public agency. For example, the assumed 60-mil tax levy may very well be earmarked for special purposes such as schools, libraries, and bond retirement, but for the purpose of the example, the funds generated by the tax are considered to be a portion of the funds available to the transit agency, and, as such, are considered as specific benefits that accrue to that agency. It is also assumed that the jurisdiction of the public agency in terms of the political subdivision includes all aspects of the transit system.

The supporting federal funding dimension of the problem is completely ignored. Inasmuch as the federal funds available under the 1964 Urban Mass Transportation Act are based on a *net* project cost-sharing concept, the Federal Government is a partner in the net project cost so that anything that defrays or reduces the net project cost in terms of a specific benefit would be shared proportionately by the Federal Government.

The hypothetical Ohio River Line in Pittsburgh is shown on p. 23. The line is 10.4 miles long and extends from a major terminal complex in the Golden Triangle, along the north side of the Ohio River, to the suburban community of Ben Avon, then northward into relatively undeveloped areas to pick up a proposed transit-based "new town" development. This line has some very complicated and costly construction segments such as the tube under the Allegheny River, tunnels in the downtown Golden Triangle, and high-level structures along Ohio River Boulevard. The line would consist of nine stations with 5200 parking places provided at the outlying stations in surface garages and lots. Starting from the Golden Triangle, the approximate distances between stations are 1800, 4400, 3600, 3500, 8200, 6500, and 5800 feet respectively, with the final leg from the Ben Avon Station to the new town at the end of the line, an uninterrupted four-mile run.

The Westinghouse Transit Expressway is assumed to be the type of rapid transit system that would be operated over this alignment. (Typical Transit Expressway costs are presented in "The Costs of Expanding Urban Transportation—Highways versus Rapid Transit," p. 8.) The operating characteristics of the

*These examples were developed for Westinghouse by Battelle Memorial Institute, and in turn were based on two other studies:
(1) *Allegheny County Rapid Transit Study*. Parsons, Brinkerhoff, Quade and Douglas, New York. December, 1967.
(2) *A Comparative Operating Cost Study for a Pittsburgh Rapid Transit System*. Westinghouse Electric Corporation, Vehicle Systems, Transportation Division, December, 1967.

Above—The appreciation of land values around rapid transit stations is demonstrated by three transit station developments along the Yonge Street subway in Toronto.

Table I. Ohio River Line Future Patronage Estimates

Year	Estimated Annual Passenger Trips for Pittsburgh System	Estimated Annual Passenger Trips for Ohio River Line	Estimated Daily Passenger Trips for Ohio River Line
1969	71,675,000	21,503,000	58,900
1974	79,135,000	23,741,000	65,000
1979	87,372,000	26,212,000	71,800
1984	96,466,000	28,940,000	79,300
1989	106,506,000	31,952,000	87,600
1994	117,592,000	35,278,000	97,000

The following assumptions were made in developing the total system patronage estimates:
The system will be operated 7 days a week.
The system will be operated 20 hours every day, from 5:00 a.m. to 1:00 a.m.*
Two minutes is the minimum permissible system headway, and 20 minutes is the maximum permissible headway.*
The average station stop time at downtown stations is 25 seconds, at urban stations is 20 seconds, and at outlying stations is 15 seconds. This results in an average operating speed on the line of 37.2 mph.
Annual patronage is assumed to grow at a rate of 2 percent compounded annually.
None of the trains will have attendants.
The minimum train size is one car.

*These conditions were specified by the consultant. Westinghouse believes that it is both practical and desirable to maintain 2-minute service, 24 hours.

Table II. Ohio River Line Benefits of Capture Strategies

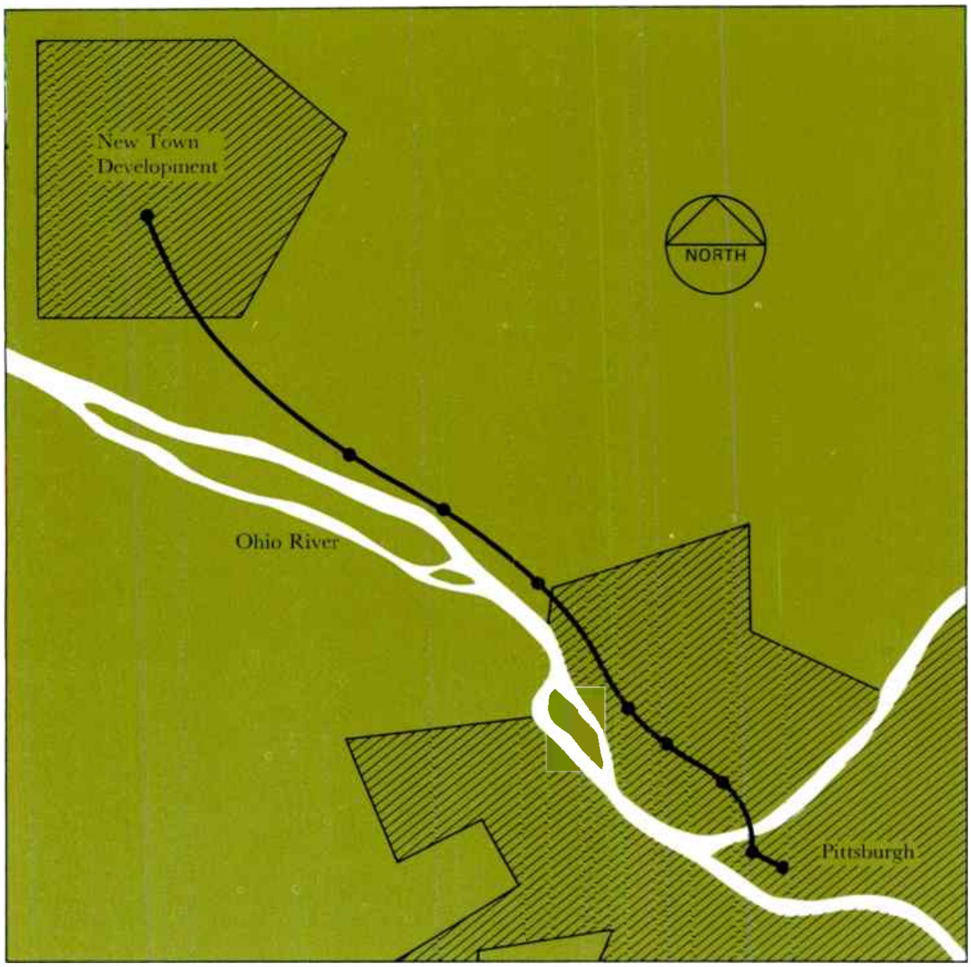
Present Value of Specific Costs:		
Fixed (right-of-way, tracks and structures, hardware, and construction)		$140,964,000
Variable operating and maintenance		70,685,000
Loss of real estate tax (on right-of-way land)		7,393,000
Excess condemnation of transit-related land		29,440,000
Land development costs		35,884,000
Total		$284,366,000
Present Value of Specific Benefits:		
Fare-box revenues*		$125,598,000
Salvage value of land		6,454,000
Right-of-way rental		15,405,000
Urban renewal improvement (sale of excess urban renewal land)		1,400,000
Sale or lease of developed land from excess condemnation (over 15-year development period)		105,900,000
Total		$254,757,000
Present Value of Net Project Costs		$ 29,609,000
Percentage of Specific Costs Covered by Specific Benefits	90%	
Percentage Covered by Optional Strategies Only	46%	

*Present value of the future stream of annual revenues derived from operating the line over a 25-year period at a 5-percent discount rate, assuming a $0.30 fare for all users.

Transit Expressway system are well suited to the rugged Pittsburgh terrain due to the system's inherent ability to negotiate somewhat steeper grades and sharper curves than possible with steel-wheeled systems. Thus, the system offers the opportunity to reduce construction costs through the elimination or shortening of tunnels and the substitution of elevated structures. Moreover, the Transit Expressway's quiet operation makes it acceptable both in the central business district and in residential neighborhoods.

A series of annual patronage estimates were made for the entire Pittsburgh rapid transit system. To develop similar estimates for the Ohio River Line segment of the system, it was assumed that all patronage estimates for the Ohio River Line would be approximately 30 percent of the total system estimates. The estimated future annual patronage of the Ohio River Line is shown for five-year intervals in Table I.

The results of implementing a combination of several applicable capture strategies to the Ohio River Line over a 25-year period are shown in Table II. As shown, the conventional benefits of fare-box revenues and salvage value of land are supplemented with optional right-of-way rentals to utilities, sale of urban renewal land, sale of transit developed land in the new town, and sale of other transit-related land. The present values of the specific costs and benefits for these examples contain all the applicable transit system and associated land costs/benefits for each situation. The returns on investment refer *only* to the capture strategies listed. These returns are independent of the primary and secondary benefits that would accrue independently of the application of these optional strategies. Thus, assuming that it would be legally, politically, and economically feasible to implement the suggested strategies concurrently, about 90 percent of the specific costs could be recovered including fare-box revenues—or about 46 percent from the optional strategies alone. This means that some or all of the primary and secondary benefits identified previously would also have to be used to



The hypothetical Ohio River Line in Pittsburgh was studied to demonstrate the specific benefits that could result from the application of capture strategies.

justify the transit investment (increase the benefit-to-cost percentage to at least 100 percent).

The numbers generated for this particular example (Table II) were based on the assumed development of a transit related "new town" at the end of the line. That new town development was assumed to encompass some 20,000 acres, developed over a 15-year period. The size of this particular kind of development by a public agency may seem overwhelming to some; however, other less spectacular combinations of land parcel development could be shown which would demonstrate similar orders of benefit. These alternate examples could include the development of smaller parcels of central city land with much greater dollar gains. As an example, some of the transit land purchased for less than $100,000 per acre in Toronto is now being sold or leased on long-term leases for more than $2.5 million per acre (more than $65 per square foot). Spectacular price increases in central business districts are not uncommon. On the high end of the scale, land in midtown and downtown Manhattan, which three years ago sold for about $200 per square foot, is now selling for about $500 per square foot—an *increase* of over $14 million per acre. If the transit authority can benefit from even a portion of these kinds of gains, the rapid transit system might be put on an even more attractive financial basis.

This Pittsburgh example is intended only to demonstrate the order of benefits that could accrue with the various optional strategies. Since the system configuration and cost data are peculiar to the Pittsburgh situation, these results cannot be applied to other areas. Also, relatively small changes in fare structures, patronage estimates, land costs, and operating and maintenance costs would alter the results of the analysis significantly. However, the results of this Pittsburgh example and others of a similar nature have demonstrated that with careful planning, optional capture strategies could provide significant additional revenues to a regional transit authority.

The Multifunction Approach to Transit Station Planning

G. W. Jernstedt

The addition of private and community facilities to the transit interchange would fulfill the needs and desires of people, thus helping guarantee the economic success of the transit system.

In the early years of this country's growth, private investment in public transportation solved problems, contributed to growth, and made a profit. Today, most of our transit operations are termed deficit ridden (although partly because of the way we choose to amortize the financial investment). Actually, public transportation should and can be a profitable venture if the movement of people is directly related to their living and working conditions, to their recreational facilities, to educational facilities, and to other environmental factors.

Public transportation planning, when integrated with the development plans for the total urban environment, can be the largest single influence in shaping the growth of a community. But for the past 30 or 40 years, there has been no appreciable improvement in public transportation as the main thrust for directing the growth of our urban communities. The result has been a random urban sprawl which has created insufficient values to support the city center. This would not have been the case if public transportation had been continually improved to keep it a viable factor in shaping the growth of the community.

Need for Multifunctional Interfaces

If appreciable numbers of passengers are to be attracted to rapid transit from their automobiles, transit systems must provide greater convenience than automobiles. The key to the approach needed is provided by today's suburban shopping centers, which are designed to accommodate automobiles but not shoppers. The most valuable piece of land (from the standpoint of improving the interface between the shopper and the shopping center) is the rooftop of the main building, where the addition of a second function—multilevel parking—would provide the shopper with convenient elevator access to the main shopping area. But this space is usually left undeveloped, and shoppers must brave rain or snow (and automobiles) as they move on foot from mammoth parking lots to the shopping areas.

This same single-function philosophy is generally applied to today's transit stops. Most transit interfaces are in "no-man's-land"—they are in the middle of everything and yet they are no place. A more logical approach to developing convenient rapid transit would be to provide multiple uses for the transit system interfaces. In fact, the interfaces should establish the principal motivation for the existence of the transit system.

Each transit station should be a planned center, not for just shopping, or just living, or for any other single purpose, but rather to satisfy a variety of human needs and desires. For example, the Taby Center Station outside of Stockholm includes 14 separate functions—schools, apartments, a shopping center, a medical center, churches, a gymnasium, and sports centers. Pedestrian traffic is completely separated from automobile traffic.

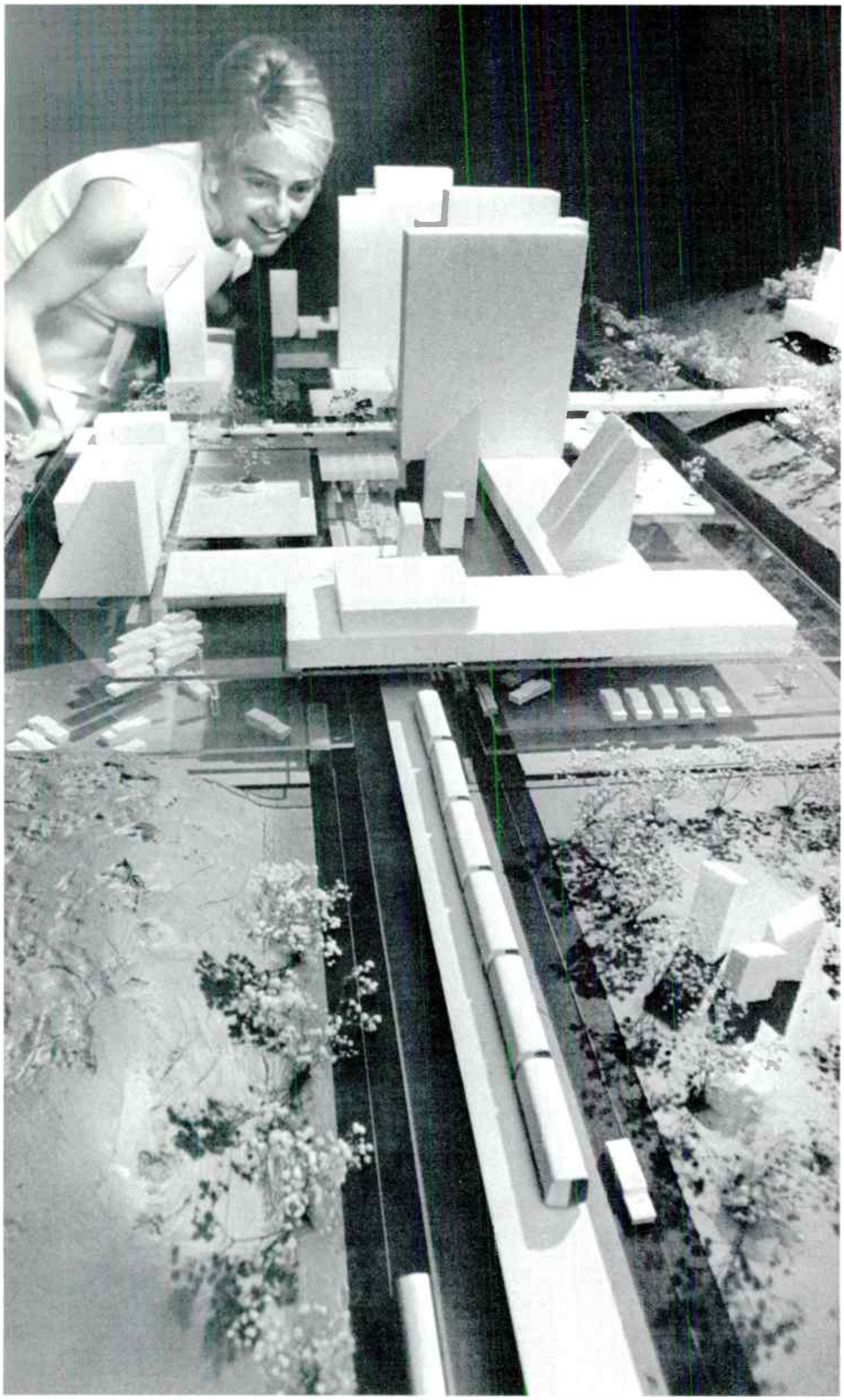
The rapid transit multifunction center might be termed the "new town" approach, but based upon rapid transit as the basic mode of transportation rather than the automobile. People who live and work in or near the center will not have to use an automobile every time they move. In fact, these transit centers will provide further impetus to the trend toward apartment living in this country. Traditionally, less than 10 percent of the population of most of our major cities have been apartment dwellers, as contrasted with European cities where apartment living has been at least double that of U.S. cities. However, that pattern is already changing. Climbing construction costs, rising interest rates, and increasing real estate taxes have already initiated the trend toward apartment living, especially for people in the moderate income range. As better rapid transit systems develop, the convenience of good transportation will make nearby apartment living even more desirable. The trend should be especially strong in both newly-married and older-age groups.

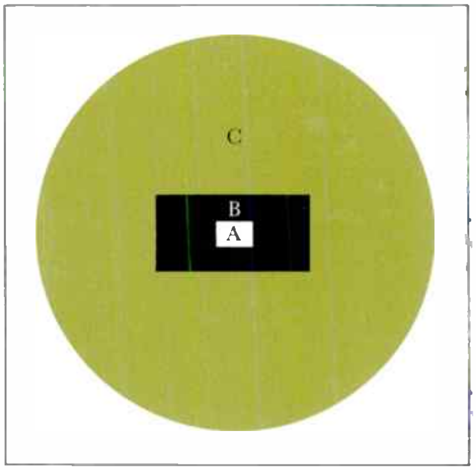
We know how to do this kind of multifunctional planning, but have done so in only a few locations—for example, the PanAm Building in New York City. And even there, little regard has been given to really maximizing personal mobility. Walking from the vertical elevators to the horizontal elevators (subway) in the PanAm center is something like negotiating an underground maze. With really advanced planning, transit center interfaces can be designed so that commuters move from vertical elevators to horizontal transportation by merely crossing a lobby.

Effective transit planning must also include more than the interfaces at single stations; it must relate one station with another. For example, schools located at a center away from the city center can be designed for use by families living at stations nearer the city so that children

Table I. Typical Land and Facilities Values for Toronto Transit Centers

Area	*Sq Ft*	*Value Before Transit*	*Value 5 Yrs After Transit*	*Increase After Transit*	*Cost of Developing Area*	*Value 5 Yrs Later*	*Increase After Transit*
A	200,000	$ 400,000	$ 1,600,000	4×	$10,000,000	$17,000,000	+70%
B	2,000,000	$ 4,000,000	$ 12,000,000	3×	$40,000,000	$68,000,000	+70%
C	25,000,000	$50,000,000	$100,000,000	2×	—	—	+50%





1—*(Left)* Each transit station should be a planned center, combining many functions to satisfy a variety of human needs and desires. New technology, such as that embodied in the Westinghouse Transit Expressway, can make transit systems so quiet that their stations can be incorporated into commercial and residential centers such as that shown in the model.

2—*(Top)* The Taby Center Station outside of Stockholm includes 14 separate functions, such as schools, apartments, a shopping center, a medical center, churches, a gymnasium, and sports centers.

3—*(Bottom)* The development of land around a transit station can be characterized by three areas: about 200,000 square feet is directly applicable to the transit station (A); about two million square feet includes facilities directly related to functions located at the transit stop (B); and an area of about one-half mile radius (C) will be directly influenced by the rapid transit station.

A Pedestrian Mobility System for Urban Centers

The Post Oak transit system, planned for construction in mid-1970, will tie together the major activities of a large urban center. This new and unique approach provides convenient pedestrian mobility within the center, and interfaces with other modes of mass transit feeding the center from outside.

Post Oak is an urban center within the city of Houston, Texas. The center, when completed, will include office towers, a hotel, department stores, and a shopping mall complete with entertainment, restaurant, financial, and other personal service facilities. The transit system, as envisioned, will serve these facilities in a horizontal mode in much the same manner that an elevator serves a high-rise tower.

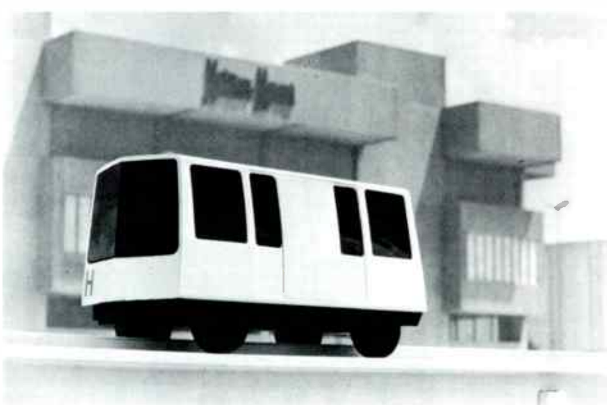
The first phase of the transit system will consist of 4800 feet of double elevated guideway, grade separated from pedestrian and automobile traffic and passing directly through the buildings it serves. Passenger lobbies within the buildings will provide direct access to building elevators.

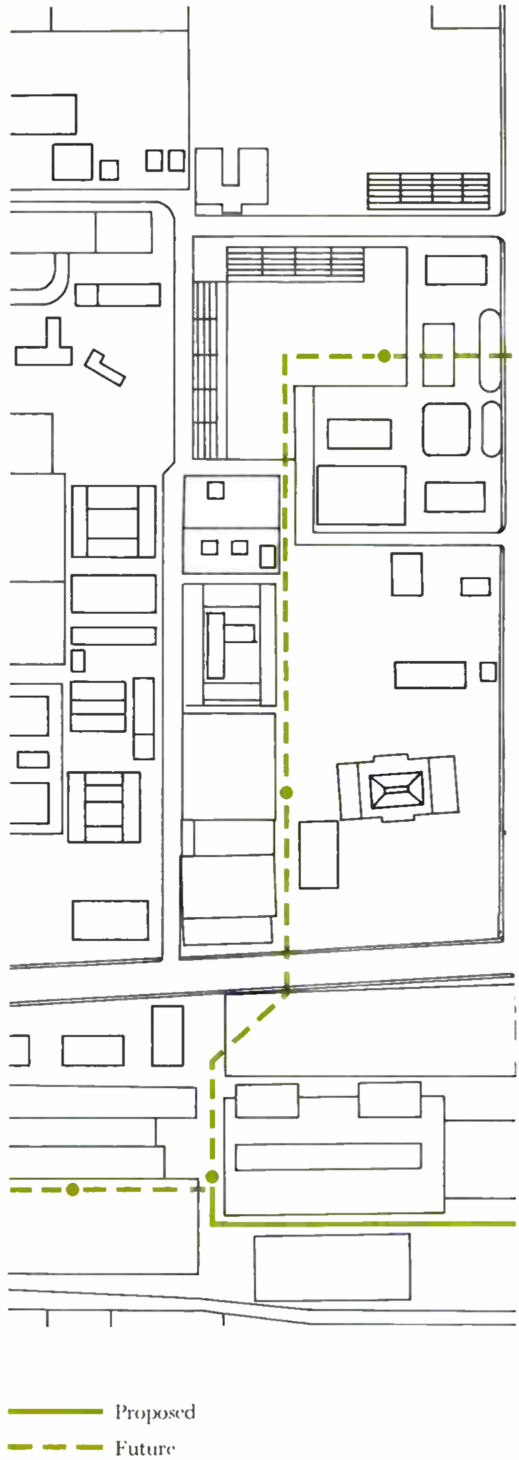
The system will use small 16-passenger cars (32 passengers with standees), rubber-tired and electrically powered. In addition to cars and guideway, the total system includes switches, an electric power system, an automatic train control system, stations, maintenance and cleaning facilities, and storage guideway for cars not in use.

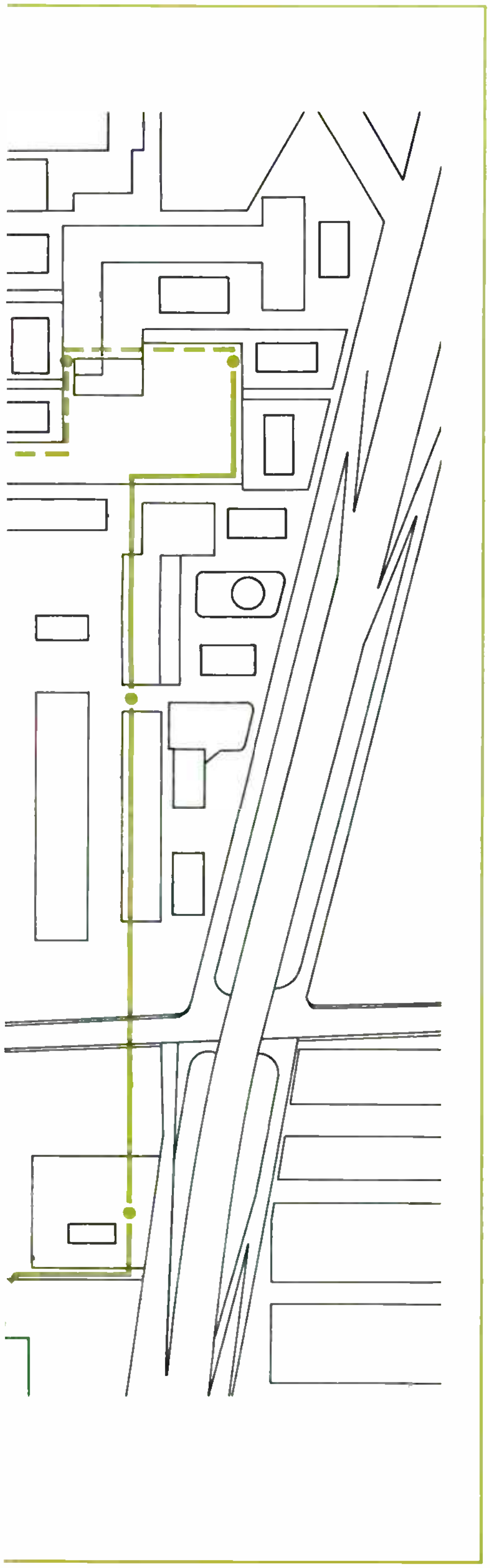
The cars may be operated as single or multiple-car trains on headways as frequent as 75 seconds to satisfy passenger demand. Overall safety of train operations is a function of the automatic train control system, which controls train separation, routing, speed, precision stops, direction, and doors (car and lobby).

Guideway switches are used to achieve a spur-end turn around on the double guideway configuration, and at selected points for crossover of the guideway. The crossover arrangement will permit taking a section of guideway out of service or bypassing a disabled train.

For the first time, it will be possible to descend by automatic vertical transportation, walk across a lobby, and continue the trip by completely automatic horizontal transportation. This new level of personal mobility will create new values for the Post Oak Center and point the way to providing such vertical-horizontal transportation interfaces in transit corridors and even for downtown distribution.







can utilize the horizontal transportation without crossing a street, while taking advantage of unused transit capacity in the direction opposite from the rush hour peaks.

Economic Potential of Transit Station Centers

In the next decade, at least ten major new rapid transit systems will be started. This activity will generate at least 250 new stations for potential development. Also, the five existing major systems are planning to increase size and build new lines, which will add at least 50 more stations. And finally, older stations should also be considered for redevelopment, which would add another 200 potential locations for transit station centers.

The development of land around a transit station center might be classified as shown in Fig. 3. Note the three areas (white, black, and color) of development. The white area (A) is covered by existing condemnation legislation for land directly applicable to a transit station, which amounts to approximately 200,000 square feet. The black area (B) is mentioned in some of the new legislation currently before Congress. These laws in essence cover the area directly affected and influenced by the rapid transit investment. This land area is typically 1000 by 2000 feet, or about two million square feet, and would include facilities directly related to functions located at the transit stop such as living, parking, education, and shopping. The color area (C) has been defined by examples in Sweden. This is the area that can be expected to be influenced by rapid transit, bounded by a radius equal to the maximum convenient walking distance to the station (approximately one-half mile).

The economic potential for these three areas can be illustrated by the average development cost of land and facilities for the Toronto subway, shown in Table I. The transit system cost apportioned to one station could be considered for this example to be about one mile at a cost of $10 million—which is high for an elevated Transit Expressway system and very low for a tunneled conventional steel-wheel system.

It should be evident that with properly developed station interfaces, the increased value in the transit station developments more than offsets the cost of the horizontal transportation. This can be likened to the floors of a building supporting the cost of the building elevator. The problem for horizontal transportation is that it has been impossible in the past to corral all the builders, developers, and local governments to plan and carry out such a creation.

Land Acquisition

Land acquisition is obviously the critical step in any redevelopment effort. In some cases, the Federal Government can provide the means for obtaining the necessary land. Money is already available for advanced land acquisition, and the proposed law now in Congress would include additional land around the station (black area in Fig. 3).

An alternative approach, a new method of private land acquisition, might be considered. The land owner would become a limited partner and thus be made more interested in participating in the development of a project.

For low-income housing, a station-area plan might be developed primarily around living and schools. Those stations probably would be placed on land classed as "passed over," similar to the Prudential site in Boston, where land can be procured by a local authority and the buildings and facilities constructed by private interests.

Although not all station sites will have high development opportunity, rapid transit certainly can be justified more readily when it can be designed to contribute to the overall development of the environment. Once rapid transit has been demonstrated as the key to urban development and redevelopment, public support will be forthcoming, and public transportation can again become a profitable venture.

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The Urban Transportation Laboratory

The urban transportation laboratory is moving out of the engineering and research buildings and into the urban interface.

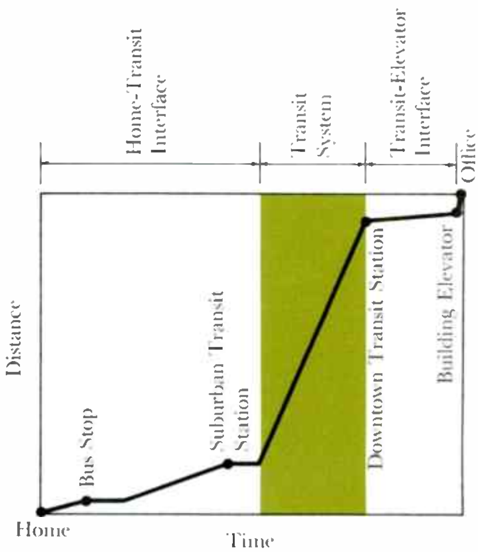
Where is this urban interface? It has many locations—the most obvious, of course, is between the transit system station and the various living, recreational, and business functions. Examples are between the transit system and the apartment house; between recreational facilities and the transit system; between a supermarket and a transit station.

These interfaces can be even more important to the improvement of our total urban environment than the actual transportation mode selected. For example, on a trip from home to office each morning, the commuter may spend more time in the interfaces than on the transit system. Thus, we could spend millions of dollars to speed the rapid transit another 20 miles per hour, but only cut trip time by a small fraction; on the other hand, a comparable amount of money spent on stations and feeder systems could contribute a much greater time saving. For example, improving the control system to permit splitting the train in half and running these shorter trains twice as frequently would reduce the average waiting time by as much as half. And more important, all these improvements would make the interface of transportation and its environment a more desirable place to be.

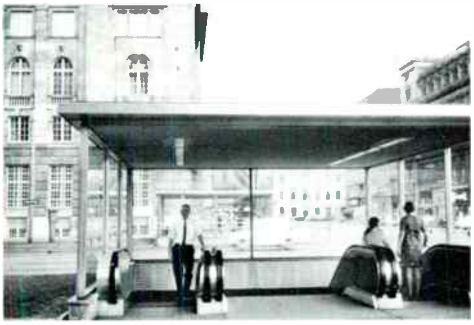
The urban interface is where the significant changes are now occurring and where more new ideas must be introduced and tested. Instead of doing the development on a model on a laboratory bench, it must be accomplished in actual demonstration. But a major limitation is the developer's hesitancy to try new ideas. Thus, application is lagging technology. Perhaps the use of government funding to assist private developers will utilize more of the available technology in line with the needs of the urban community.

West Berlin—**Moving stairways connect shopping centers, restaurants, and high-rise buildings at four different levels with the rapid-transit system one level below ground.**

Stockholm—**Multilevel arrangements are used at the satellite-city transit stations to keep pedestrian traffic separated from automobiles.**



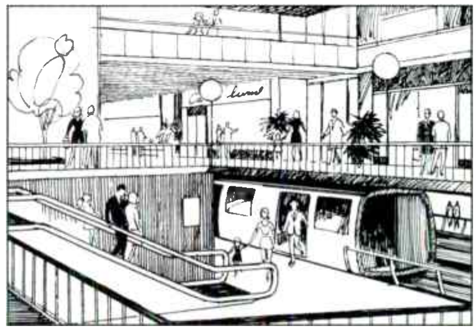
Typical time-distance curve for a suburban commuter: The commuter walks to the bus stop, waits for a feeder bus, rides the bus to the transit stop, waits for transit vehicle, rides the transit system (the efficient portion of the journey, as indicated by the steepness of the curve), walks from the downtown transit stop to his office building, and takes the building elevator to his office. For this commuter, the real opportunities for achieving significant time saving are the interfaces with the transit system rather than the actual transit system.

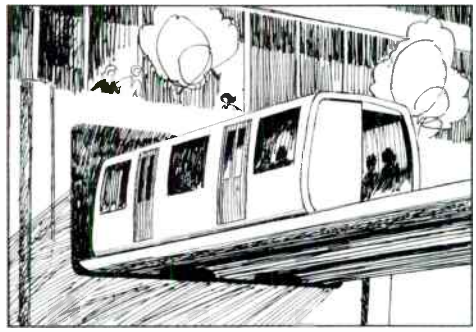


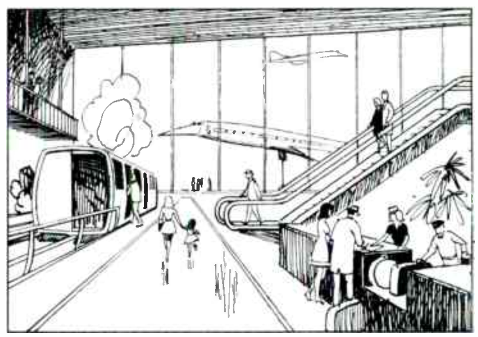
Boston—Ground transportation systems are expensive, but the expense can be reduced by multiple use of facilities. In Massachusetts, there is beginning a rather widespread use of land directly over the highway. The Massachusetts Turnpike will have buildings such as offices, supermarkets, and parking garages built over the right of way. The income from these building rights will help to maintain existing highways and to build new highways.

Vienna—Moving stairways carry pedestrians under the streets at intersections so that people do not have to cross the street in traffic.

Toronto—A good example of improving the most common interface—the transit station to the apartment house—is to locate the apartment near the station. But the commuter must walk outside to reach the station, and land over the station has been wasted for potential income. Toronto now knows how to do it better, and in one of the new transit centers now going up, a station will be located inside an apartment house.







In the future, our transportation interfaces will have to be a much more enjoyable environment. The actual station should disappear, and the transit car should blend in with perhaps restaurant facilities or recreational facilities. Living or business facilities located directly above or below the interface will be readily accessible by moving walkways, moving stairways, or elevators.

Completely automatic and quiet rapid transit (such as Transit Expressway) can enter an apartment or office building. The exchange then takes place at the interface of the vertical elevator and the horizontal conveyance.

Interfaces that can be improved in the United States at this time are those between the high-speed railroad, the rapid transit system, the bus system, and the elevator. At some interfaces, such as this sketch suggests, all transportation forms may be present.

Side-Look Radar Maps Ice in St. Lawrence Seaway

Radar mapping of the St. Lawrence River and Gulf of St. Lawrence has been used to test the effectiveness of side-look radar as an all-weather aid to ice observation. It is faster and provides more information than visual methods, and it can be used in any kind of weather.

The reason the radar image provides more information than visual observations is that it presents what amounts to two views of the same area, from which experienced interpreters can draw conclusions about the area. (See the images below.)

The top trace was produced by radar return signals through an antenna that accepts like-polarized signals; that is, the signals are accepted only if their electromagnetic polarity is the same as that of the signals originally transmitted. The polarity of the signals was in the vertical plane. A second antenna accepts only cross-polarized signals, which have been affected by water, ice, or other surface materials in a manner that rotates their polarization to the horizontal plane.

The ice mapping was done for the Canadian Department of Transport by the Westinghouse Aerospace Division as part of Canada's effort to improve its airborne ice reconnaissance. The system used is an outgrowth of work in military reconnaissance radar; it is applied primarily to petroleum and mineral exploration.

Images of the St. Lawrence River near Quebec City are part of a radar-generated map made to test the effectiveness of radar for all-weather ice mapping. The top image was made by like-polarized return signals; the bottom by cross-polarized signals. The two images provide more information than visual observation does.

Use of TV Monitors Reduces Expense of Display Terminals

With increasing use of the computer in business and industry, an increasing amount of output information has to be distributed to the departments using the computer. Most of it is redundant for any one user, but all of it usually is printed out and the users then scan it for the required information.

Remote access to the computer from display terminals for individual users makes it possible for users to ask only the relevant questions and receive the required answers. However, such individual display terminals have been slow in achieving wide use, mainly because they require time-sharing capability in the computer and because they have been expensive.

To provide a low-cost display system, the Westinghouse Alpha-Numeric Display (WAND) has been developed. It is a digital-to-video converter combining magnetostrictive delay-line memory with a raster scan deflection system operating at the standard 525-line television rate, thus allowing standard television monitors and broadcast receivers to be used as display terminals. WAND is manufactured by Canadian Westinghouse Company, Ltd., and distributed in the United States by the Westinghouse Specialty Electronics Division.

The system consists of an input buffer that accepts data from the transmission line and stores it on a circulating delay line. The incoming information is correctly sequenced on the delay line as determined by the system timing, which also produces the synchronizing signals and other control signals required by the system. A character row of information, still in digital code, is transferred from the delay line to a row register, and the output from this register is circulated rapidly in synchronism with the television line scanning. The characters in the row are produced as video by processing the digital words seven times through the character generator to build up the characters in a five-by-seven dot matrix. On completion of the readout of the first character row, the next row is transferred from the delay line to the line register and the process repeated to build up the complete display.

The unit is modular in construction so that it can readily be expanded to more complex systems. Dial stations, or a keyboard with many editing features, can be used for access to the computer.

One application suited to the WAND system is display of transportation arrival

The WAND display system provides video readout on standard television monitors and broadcast receivers for a wide range of digital inputs including teletype, computer, data link, ticker, and keyboard. Digital information is converted to alphanumeric form at speeds up to 300 characters per second.

and departure schedules. Another is an integrated stockbroker's display system that gives each broker immediate access to any of the information services available in the office (see photo). In addition, large monitors can be paralleled on the ticker and the newsreader video channels for public viewing.

Other applications are in industrial process control and power generation. Since the WAND system can provide more readout than the traditional numeric counters, more data details can be included. One installation is in a steel mill to provide data to operators of mobile cranes.

Facilities Inaugurated for Fast Breeder Reactor Programs

Major new facilities for developing fast breeder nuclear reactors have been inaugurated at the Westinghouse Advanced Reactors Division, Waltz Mill, Pennsylvania. They provide more than 128,000 square feet of laboratory and office space, with older buildings at the site providing an additional 78,000 square feet.

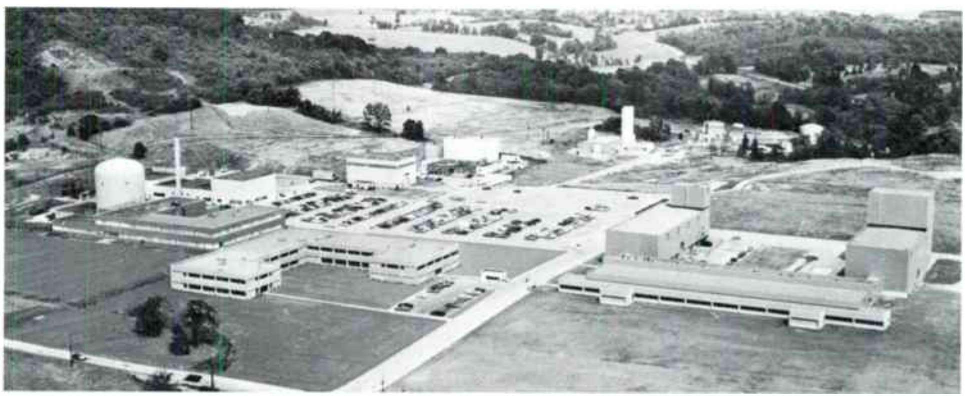
In addition to the Advanced Reactors Division's own development program, the Waltz Mill site provides space for the division's design work for the U.S. Atomic Energy Commission's Fast Flux Text Facility (FFTF) to be built at Richland, Washington. The FFTF is the major test facility for the AEC's liquid-metal fast breeder reactor program. It will be used for irradiation testing and postirradiation examination of fuels and materials being evaluated for use in breeder reactors.

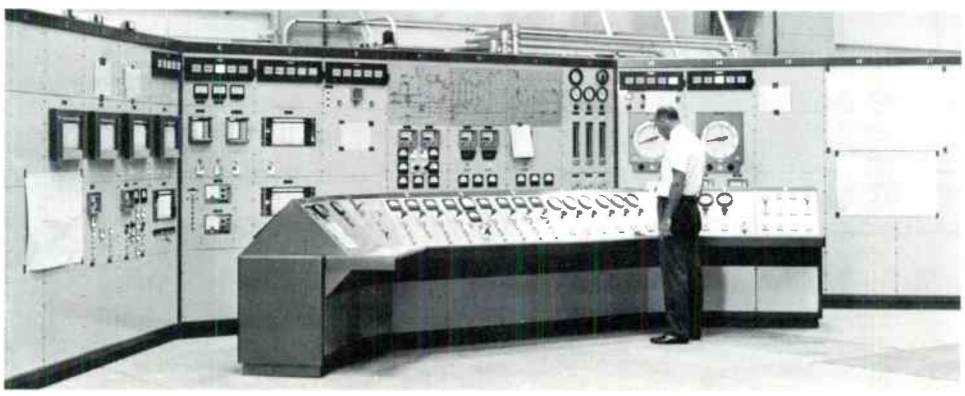
The division's own program includes design and testing of a variety of potential fast breeder materials and components to determine how well they perform in contact with liquid sodium, which will be the coolant in the Westinghouse reactor. Thirty-one electric utilities have joined Westinghouse for the project-definition phase of the AEC's fast breeder program. Moreover, 22 electric utilities—including some of those supporting the company's project-definition phase—have been sponsoring preconstruction research, design, engineering, and development.

The major task at Waltz Mill is to develop specialized electrical, mechanical, and pneumatic mechanisms to operate reliably in hot sodium and inert-gas environments, so one of the new installations is a facility for operating mechanisms under sodium. Its large sodium-filled tank provides temperatures up to 1200 degrees F.

A fuel-handling test facility will provide full-scale operating experience with reactor components, refueling and equipment-handling machinery, environmental control systems, and viewing equipment before final design and construction of the first liquid-metal fast breeder reactor plant. After the first plant is on line, the facility can be used for training operators and testing new components.

A postirradiation facility provides for complete nondestructive and destructive examination of fuel rods, experimental capsules, and reactor components. Other laboratories and facilities besides those mentioned will aid in the design, development, and testing of both liquid-metal and pressurized-water reactors.





Top—**Laboratory and office space have been more than doubled at the Westinghouse Advanced Reactors Division.** ***Bottom***—**Engineers monitor and control the main sodium test loop with this panel and console. The loop is part of the division's equipment for developing a fast breeder nuclear reactor that will use liquid sodium as coolant.**

Nuclear Power Components Shipped from Tampa

A steam generator 68 feet long, 14 feet in diameter, and weighing 330 tons, along with a pressurizer weighing 85 tons, were the first nuclear components shipped from the new Westinghouse plant in Tampa, Florida. The equipment was shipped to the Virginia Electric and

Power Company's Surry Nuclear Power Station, under construction on the James River in Surry County, Virginia.

A tug towed the barge shipment from old Tampa Bay into the Gulf of Mexico, through the Okeechobee Waterway, up the Intracoastal Waterway to Norfolk, Virginia, then about 17 miles up the James River to the plant site. The trip took ten days.

The steam generator was shipped in two pieces: the upper shell, or steam drum, and the lower shell, which contains approximately 45 miles of Inconel tubing.

Steam generator and pressurizer for a pressurized-water reactor in the Vepco Surry Nuclear Power Station were shipped recently. The steam generator was shipped in two pieces, weighing about 120 and 210 tons each.

The two sections were to be welded together in the field.

Westinghouse is providing two 800,000-kW nuclear steam supply systems for Vepco's Surry I and II nuclear power plants. The first plant is scheduled for commercial operation in the spring of 1971; the second, a year later. Each plant will have three steam generators manufactured at Tampa.

Products for Industry

Thyristor Drives are a new line of solid-state adjustable-speed dc drives employing integrated circuits and SCR's to meet a broad range of performance requirements with high reliability. The drives cover the range from ¼ to 40 horsepower and come in compact standardized packages. Standard speed range is 30 to 1 and speed control regulation 2 percent, but the units are capable of a 100-to-1 speed range and 1-percent speed regulation with an optional tachometer kit. A manual control option is available with the 2-, 3-, and 5-horsepower models. *Westinghouse Industrial Systems Division, 4454 Genesee Street, P.O. Box 224, Buffalo, N.Y. 14240.*

Redac V-C supervisory system performs control, indication, and data-acquisition functions for electric utilities, pipelines, and other users of such systems. The high-speed solid-state equipment can be used in a wide range of applications ranging from single-station systems to large multistation systems operating over wide-band channels. The design permits system arrangements varying from computer processing of data to computer-directed system operation. *Westinghouse Relay-Instrument Division, 95 Orange Street, Newark, N.J. 17101.*

Life-Line D motors are a new line of ac squirrel-cage motors in the range from 250 to 2000 horsepower. They have up to twice the horsepower of previous motors of the same size because of the insulating materials used and because high-speed computers are employed to perform a complex optimizing analysis and design of air-flow paths to maximize cooling. Time-tested Thermalastic epoxy insulation, which incorporates mica, is used; copper resistance rings are cast centrifugally for inherent balance; removable side panels allow direct and easy access to stator windings for inspection and maintenance; and the shaft has high stiffness while permitting adequate air flow. *Westinghouse Large AC/DC Motor Division, 4454 Genesee St., P.O. Box 225, Buffalo, N.Y. 14240.*

Electric fire truck and pickup truck are for in-plant use. Both operate on six 6-volt lead-acid batteries and can travel 12 miles an hour. The truck can carry loads up to 500 pounds. *Westinghouse Repair Division, 26701 Redlands Blvd., P.O. Box 712, Redlands, California 92374.*

About the Authors

G. W. Jernstedt has been associated throughout his career with groups whose main objective has been to develop new concepts and techniques. As Director of Transportation Activities, he is not only responsible for the Westinghouse Transportation Division but also for helping bring forth tomorrow's technical and social advances in the transportation area.

Jernstedt joined Westinghouse in the engineering department of the Meter Division in 1936 and, a year later, graduated from Newark College of Engineering with a BS in chemical engineering. He did graduate work at Polytechnic Institute of Brooklyn and, on a Westinghouse Lamme Scholarship awarded in 1939, earned his master's degree in electrochemistry at Michigan State College. He holds many patents in electroplating and metal finishing.

In 1942, Jernstedt became a member of the liaison engineering group at East Pittsburgh, whose responsibility was to coordinate engineering effort throughout the Corporation. He then was made Manager of Electroplating Projects in 1946. In 1951, he became Engineering Manager of the Special Products Department, a group whose function was to develop new ideas into products.

Jernstedt joined the manufacturing organization in 1954 as Director of the Headquarters Manufacturing Laboratory, where new manufacturing techniques and equipment are developed. In 1957, he was made Manager of the Manufacturing Planning Department, which included responsibility for the Laboratory and for such other functions as planning plant layouts and facilities. His work earned him the Westinghouse Order of Merit in 1961. Jernstedt's next appointment was as General Manager of the Transportation, Repair, and Industrial Equipment Divisions. When those divisions were realigned in 1968, he assumed his present position.

John S. Robinson is Manager, Business Development, Power Systems Planning—Distribution. Among his responsibilities in that post have been many special studies involving electrical distribution and load growth analysis, including studies on urban transportation costs and urban land use for the Westinghouse Sixth Power Forum.

Robinson joined Westinghouse on the graduate student training program in 1959 after earning a BS degree in Electrical Engineering at Washington University, St. Louis, Missouri. He has also done graduate work there in applied mathematics and computer science. Robinson worked first in Industrial Equipment Field Sales. He moved to Electric Utility Field Sales in 1962, and in 1965 he joined Electric Utility Headquarters Marketing. He assumed his present position in 1968.

Robinson has coordinated Westinghouse participation in industry technical meetings on electrical distribution and has coauthored and edited the Westinghouse Underground Distribution Handbook. He also participated in the design and layout of the experimental residential streetlighting system for Coral Springs, Florida.

Robert E. Skorpil graduated from the State University of New York at Stony Brook in 1962 with a BS degree in Engineering Science. In 1967, he received an MBA degree in Marketing from Adelphi University. He worked first with Long Island Lighting Company, forecasting area power requirements and planning distribution system reinforcements by use of computer techniques.

Skorpil joined Westinghouse in 1967 as a marketing analyst in Power Systems Planning. He is responsible for communications programs and trade association activities, and he is editor of *Current News*, a loadbuilding publication for the electric utility industry. As part of his market development responsibility, he conducted special studies on electric transportation costs and benefits that were used in the Westinghouse Sixth Power Forum.

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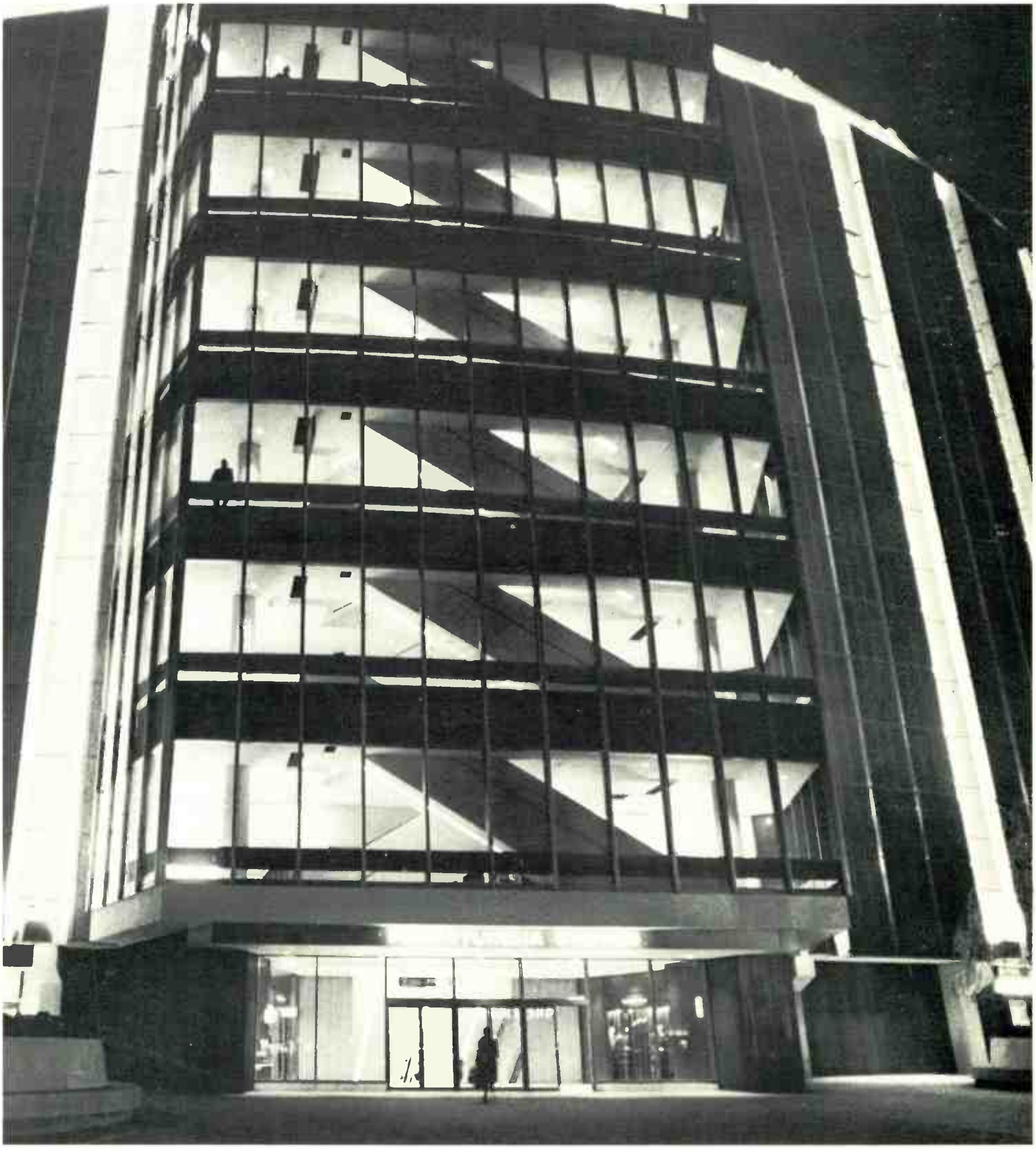

Transportation interface at Madison Square Garden. (Information on contents page.)