Chapter 4

TRANSIT SYSTEM DESCRIPTIONS

There are eight operating rail rapid transit systems in the United States and three more in the process of planning and construction. Rail rapid transit systems are also under consideration in other cities, but none has yet reached the point where there is a definite commitment to build a rail rapid transit system in preference to some other mode of urban mass transit. Visits were made to these operating transit properties and planning agencies during the course of this study. A list of the organizations and individuals interviewed is presented in appendix F.

Five operating rail rapid transit systems were selected for detailed examination. They represent a wide range of characteristics and forms of train control technology. They vary from old to new, simple to complex, and essentially manual to highly automated. This chapter provides a brief description of the five operating systems and the three currently under development.

BAY AREA RAPID TRANSIT (BART)

System Characteristics

BART is the newest rail rapid transit system in the United States, and the most highly automated, It also serves the largest geographical area of any operating rail rapid transit system in the country. As shown in the vignette map above, the BART routes form an X-shaped pattern, whose dimensions are roughly 26 miles East-West and 30 miles North-South.

From the route map it is evident that BART serves two major purposes: to connect the East Bay suburban communities with the Oakland metropolis and to link all of these with San Francisco by means of the Transbay Tube under San Francisco Bay. The Oakland "Wye," a junction and switching complex at the eastern end of the

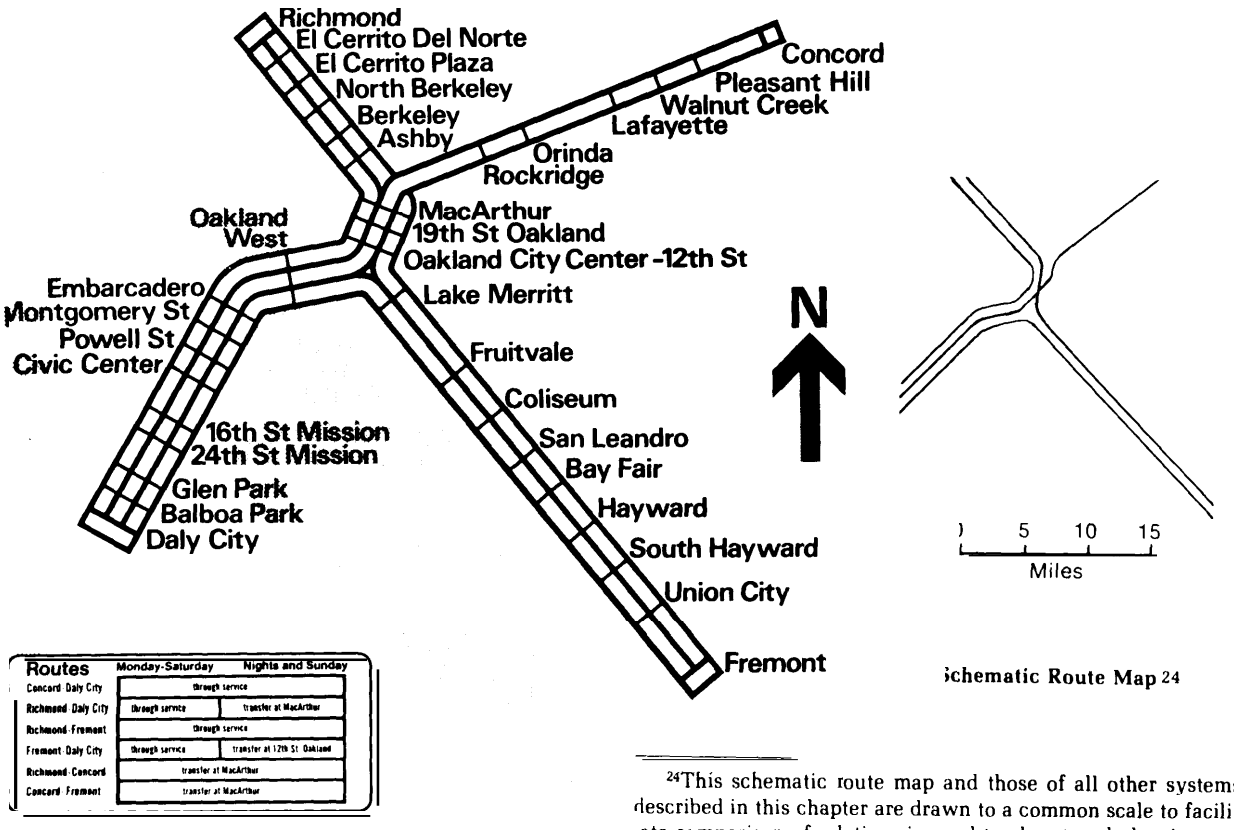

FIGURE 24.—BART Route Map

Schematic Route Map[24]

[24]This schematic route map and those of all other systems described in this chapter are drawn to a common scale to facilitate comparison of relative size and track network density.

TABLE 2.—BART System Facts

ROUTE MILES	Surface	25	TRAIN LENGTH (cars)	Max.	10
	Elevated	23		Min.	2
	Subway	23	SPEED (mph)	Max,	80
		71		Av.	40
STATIONS	Number	34	SCHEDULED MINIMUM HEADWAY (min.)		[2]6
	Avg. Spacing (mi.)	2.1			
VEHICLES	Number	450	MANNING	No. in Train Crew	1
	Weight (tons)	28.5–29.5		()& M Employees/Car[3]	[4]2.6
	Length (ft.)	70–75	PASSENGERS	Annual (mill.)	28,8
	Capacity (psgrs.)[1]	144		Av. Weekday (thou.)	125
	Av. Age (yrs.)	2			
CAR MILES	(mill./yr.)	21.6	TRAIN DEPARTURES PER DAY (each way)		280

MAIN LINE TRAIN CONTROL

Train Protection	Automatic train separation and overspeed protection with advisory cab) signals, automatic rolling, and interlocking control.
Train Operation	Automatic speed regulation, station stopping, and door operation
Train Supervision	Centralized computer control with centralized manual control and local manual control available as back-up modes

(1974/75 Data)

[1] Full complement of seated passengers plus standees in reasonable confort; crush load is somewhat greater.
[2] Will he reduced to 2 minutes when system is fully operational.
O&M (operations and ma intenance) employees include O&M supervisors, but not station, administrative, engineering, planning and ma nag ement personnel.
[4] Estimated stable year staffing.

Transbay Tube, is the engineering feature that makes it possible to provide through service, without changing trains, between any of the East Bay lines and San Francisco.

The BART system consists of 71 miles of double-track routes. ” Approximately one-third of the system is underground, one-third on elevated structure, and one-third on fenced surface right-of-way with no grade crossings.

BART has a total of 34 stations (14 underground, 13 elevated, 7 surface), with an average spacing of slightly over 2 miles.

The BART fleet presently consists of 450 cars, which are of two types: A-cars, containing the operator’s cab and train control electronics, and B-Bears, which cannot operate independently in revenue service. The non control end of A-cars and both ends of B-cars are equipped with hostling panels to permit individual car movement in the yards and on storage tracks. The basic train make-up (consist) for revenue service is an A-car at either end and up to eight B-cars between. Ten-car trains are run during peak periods, Four- to six-car consists are operated in the base period.

The maximum operating speed of trains is 80 mph. The average line speed (including station stops) is about 42 mph, At present, trains operate on 6-minute headways through the Transbay Tube and on the San Francisco portion of the system. Headways are 12 minutes on the Concord and Fremont feeder routes and on the through route from Richmond to Fremont. When BART reaches its full level of service, headways will be reduced to 2 minutes in San Francisco and 6 minutes elsewhere during peak periods,

25 The San Francisco Muni line, a light rail system, runs parallel to the BART line on 4 miles of underground track beneath Market Street in San Francisco. While the two share stations, the Muni system is not part of BART and is operated by a separate transit agency.

In fiscal 1974–75, BART carried an estimated 28,8 million passengers, for a total of nearly 447 million passenger-miles, Thus, the average length of a passenger trip was 15.5 miles, and the average duration 22 minutes. The average fare per ride was approximately 60¢.

ATC Features

Train control in the BART system is highly automated and accomplishes three major functions: (1) overspeed protection, assurance of safe separation between trains, and route interlocking control, (2) train operation, including station stops and door operation, (3) train supervision, including dispatching, schedule maintenance and adjustment. There is one operator on board the train, regardless of its length. The normal responsibilities of the operator are limited to surveillance of the track, monitoring of the train condition, and making passenger announcements. The operator can override certain automatic train operation functions, such as door closure, and can adjust some of the parameters of automatic operation, but the operator does not normally intervene in train protection and operation processes.

The automated equipment which carries out train control functions is partly on board the train, partly at the wayside and in stations, and partly in a central computer complex. Generally speaking, train protection and operation functions are accomplished by wayside, station and carborne equipment. Dispatching and schedule maintenance and adjustment are functions of the central computer, wayside equipment, and carborne equipment.

The role of the human operator in BART, either on the train or in central control, is intended to be largely supervisory in nature. The operator can also exercise certain override and back-up functions in the event of equipment failure or unusual conditions not provided for in the computer programs, Thus, the train operator can always apply emergency braking, keep the train in the station, prevent the doors from closing, or modify the train performance mode to a more restricted level. The dispatcher at central control can manually set and cancel routes, hold trains at stations, order station run-throughs, adjust schedules, insert train identification in the computer schedule, and modify train performance—although all of these train supervision functions are normally handled by the central computer.

Problems and Issues

The BART system has been the subject of intense controversy from the very beginning, Long before the first line opened for service in 1972, critics alleged that the system was too costly and too complex, partly because of unnecessary sophistication and technological innovation in the train control system design. This complexity and reliance on unproven technology, critics contend, has also resulted in a system of lower inherent reliability and serviceability that costs more to operate and

FIGURE 25.—BART Train in Underground Station

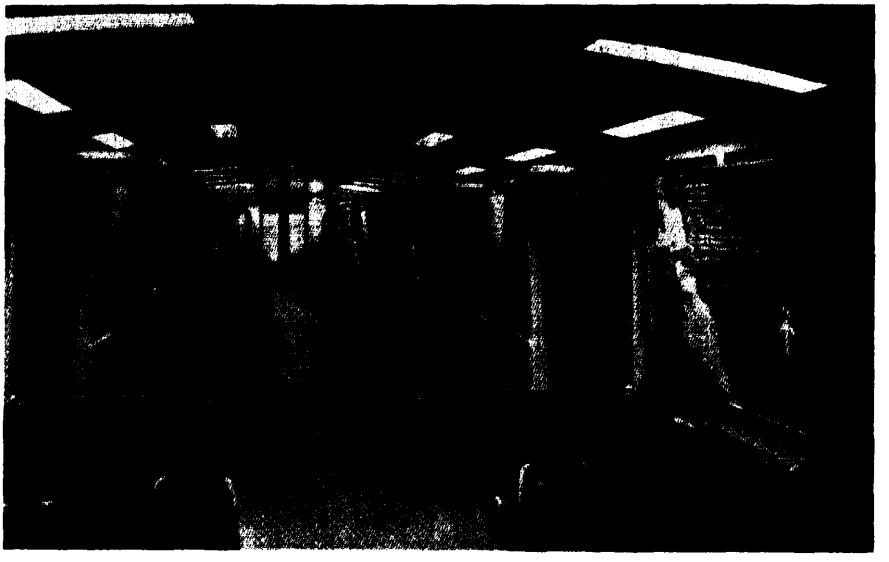

FIGURE 26.—Interior of BART Car

gives poorer service than a system employing conventional technology. It is further contended that the ATC system is basically unsafe for two reasons. First, there are automated elements that could fail and compromise the safety of train operation. Second, the human operator has been designed out of the system to the point where he has no effective means of intervention in such circumstances, except to bring the train to an emergency stop and thus degrade the performance (and perhaps the safety) of the system as a whole.

The defenders of BART rebut these charges by pointing out that the complexity is a necessary consequence of the high level of performance and sophistication required in the system engineering specifications. The design, they contend, was purposely innovative because it was necessary to break new ground in order to build a viable transportation system for a public that has had a long-standing preference for the automobile. The safety of the system is defended in two ways: on theoretical grounds, it is asserted that BART has all the fail-safe provisions of the conventional system, but accomplished in different ways that are not adequately appreciated by engineers of traditional train control equipment. On practical grounds, it is pointed out that the BART safety record is comparable to other transit systems, but operating difficulties and accidents in BART receive much greater attention because of the public controversy surrounding the system.

Fuel was added to the fire less than a month after the inauguration of service when a train ran off the end of the track at the Fremont Station. There were no fatalities and only minor injuries, but the safety of the ATC system was opened to serious question. Investigations of BART were undertaken by the California Senate, the California Legislative Analyst, the California Public Utilities Commission, and the National Transportation Safety Board. The cause of the accident was traced to a faulty crystal oscillator in the carborne electronics which, by operating at the wrong frequency, generated too high a speed command. This design defect has since been remedied by providing a redundant speed control circuit; but the investigations exposed other fundamental problems, especially in the train detection system.

As a result, the California Public Utilities Commission has issued a series of rulings which will result in additional tests and demonstrations before BART can be placed in full operation. The major area under scrutiny is the train detection system. Rail-to-rail shunting through the train axle and wheels, which decreases the signal in the track circuits and thereby indicates the presence of a train, does not always occur to a sufficient degree in the BART system. Also, there are other factors that disturb the transmission of track circuit signals and sometimes cause the train detection system to give a false indication of track occupancy. To compensate for these faults and to assure positive detection

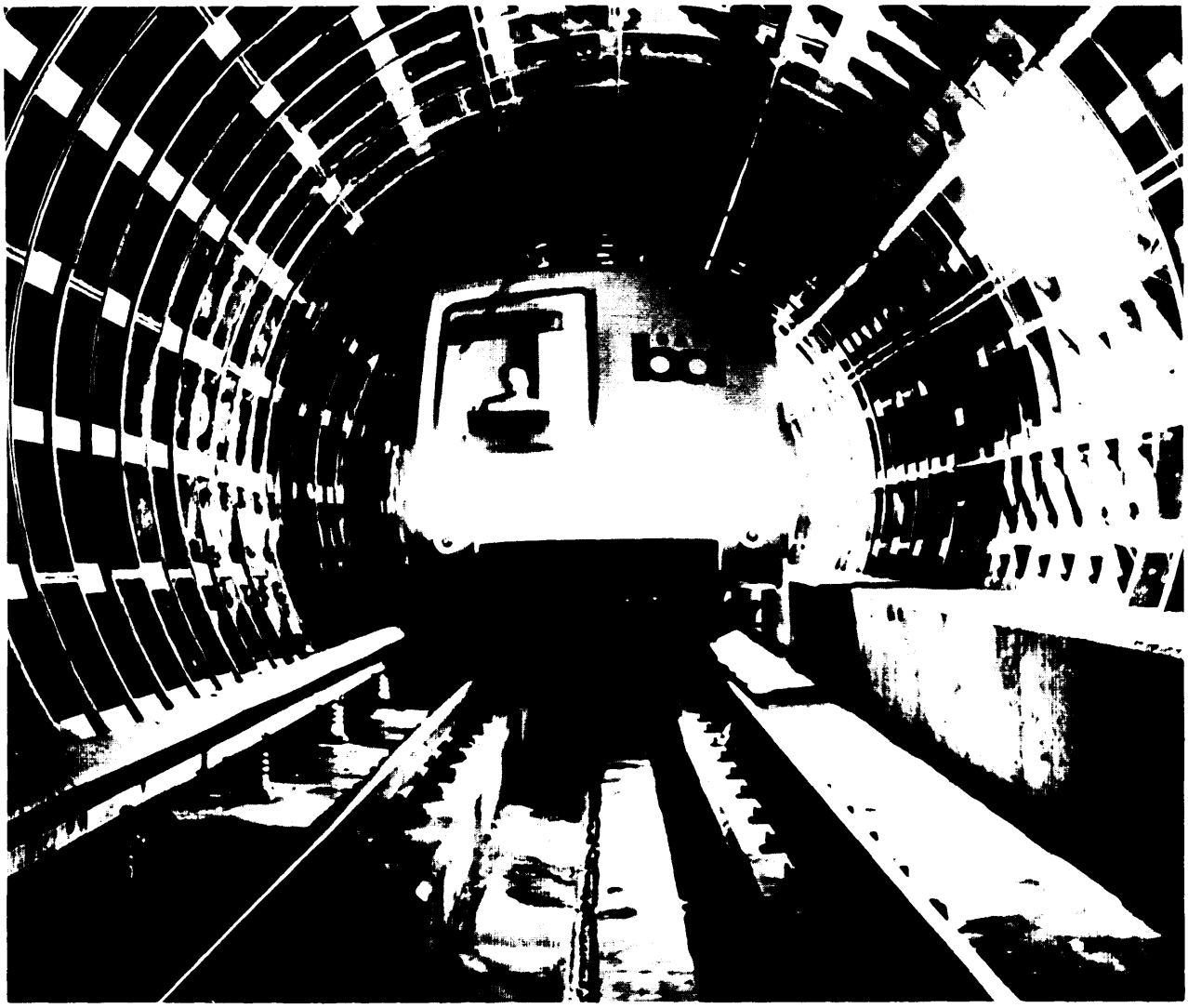

FIGURE 27.—BART Train Passing Through the Transbay Tube

of trains at all times, a logical back-up system has been installed. This involves the use of special minicomputers at the stations to monitor the outputs of the primary track circuit detection system and to clear trains for movement only if certain logical conditions and criteria are met, These design modifications are completed and tested but have not yet been approved by the California PUC. Therefore, the BART system has not yet attained full operational status.

As BART has made the transition from design and development to operations, other problems have emerged. Reliability of equipment, particularly the cars, has been disturbingly low. Most of the time as much as half of the car fleet is out of service for repairs. Of the trains dispatched in the morning, only about two-thirds complete the day without a breakdown, This has been compounded by problems of maintenance. Electronic components take somewhat longer to troubleshoot and repair and other types of components, and a higher level of training and skill is required in maintenance technicians. The carborne equipment is not easily accessible in some cases, requiring more time to get at the failed component or making it necessary to remove one item in order to reach another. Spare parts are in short supply. Often the troubles reported in service are intermittent and cannot be confirmed or located when the cars reach the yard or shop. The apparently healthy car is then restored to service, only to fail again in a short time.

System Characteristics

CTA is an integrated rail-bus transit system serving the city of Chicago and 34 suburbs in Cook County. It is the second largest public transit system in North America,[26] operating a fleet of 2,500 buses

[26]The largest combined bus-rail system in North America is the New York City Transit Authority. Considering only the rail portion of the system, Chicago is also second only to NYCTA.

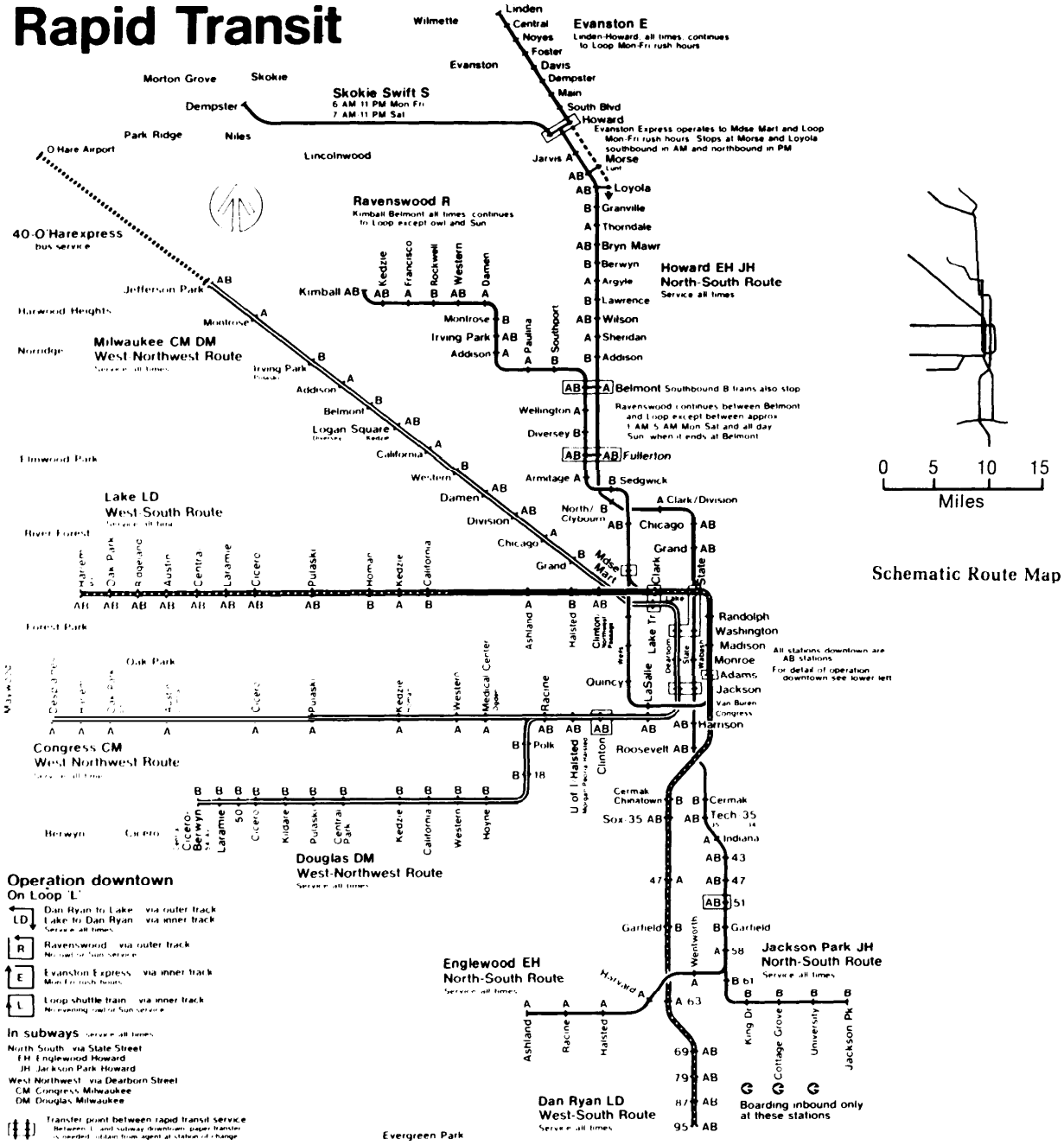

FIGURE 28.-CTA Route **Map**

Table 3.—CTA System Facts

ROUTE MILES	Surface	41
	Elevated	39
	subway	10
		9 0
STATIONS	Number	142
	Avg. Spacing (mi.)	0.6
VEHICLES	Number	1.094
	Weight (tons)	20–24
	Length (ft.)	48
	Capacity (psgrs.)[1]	75
	Av. Age (yrs.)	16
CAR MILES	(mill./yr.)	48.9
TRAIN LENGTH (cars)	Max.	8
	Min.	1
SPEED (mph)	Max.	[2]58
	Av.	25
SCHEDULED MINIMUM HEADWAY (min.)		2 1/4
MANNING	No. in Train Crew	[3]2
	O&M Employees/Car[4]	2.2
PASSENGERS	Annual (mill.)	129.2
	Av. Weekday (thou.)	512
TRAIN DEPARTURES PER DAY (each way)		1,450

MAIN LINE TRAIN CONTROL

Train Protection	Mixture of cab signals with automatic overspeed protection and wayside signals with trip stops[5]
Train Operation	Manual operation
Train Supervision	Mixture of centralized and local manual control

(1974 Data)

[1]Full (complement of seated passengers plus standees in reasonable comfort; crush load is somewhat greater.
[2]Newer cars are capable of 70 mph hut are governed to 55 mph.
[3]One-man train crew on the Skokie Swift Line and the Evanston Shuttle during off-peak hours.
[4]O&M (operations and maintenance) employees include O&M supervisors, but not station, administrative, engineering, pi, in ning and management personnel
[5]When current Ivprogram ei insta Ilations are complete in the spring of 1976.

and 1,100 rail rapid transit vehicles. The rail portion of the system consists of seven lines, of which all but the Skokie Swift line pass through or circulate within the downtown area. Two of the six downtown lines are in subways, entering and leaving by tunnels under the Chicago River. The remaining four are elevated lines that run on common tracks on the Loop El. Access to the loop area is over two bascule bridges, which are raised several times daily during the navigation season to permit the passage of ships. Thus, the throughput for over half of the CTA system is determined by the volume of traffic that can be accommodated on the tracks of the 75-year-old Loop El structure and its associated movable bridges.

CTA operates a total of 90 miles of routes (191.6 track-miles). Almost half (41 miles) are at grade. Elevated routes comprise 39 miles, and subway routes 10 miles, There are 142 stations (41 surface, 85 elevated, 16 subway), with an average spacing of about two-thirds of a mile,

CTA maintains a fleet of 1,094 cars, consisting of five types, All but four cars used on the Skokie Swift Line are 48 feet in length and of conventional steel construction. Their weight is between 40,500 and 47,000 pounds, depending on the type, The 2000-, 2200-, and 6000-series cars are operated as "married pairs, " consisting of a permanently coupled A-car and B-car. The pairs can be operated from either end as two-car trains, and they can be joined with other pairs to form trains of up to eight cars in length. The fourth type of car (the 1–50 series) is designed to operate as a single and has an operator's cab at either end. The 1–50 series cars can also be joined to form trains. The fifth type is a three-compartment, articulated car, of which there are only four, all assigned to the Skokie Swift line, These cars are about 89 feet long and weigh 93,000

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pounds. The rolling stock is of varied age. The 6000-series cars are almost 25 years old; the 2200-series was acquired in 1969–70, The average age of the cars is about 16 years.

Trains of one to eight cars are run in peak periods on headways that range from 2 to 6 minutes for individual lines. The maximum speed of trains is 50 to 58 mph, depending on the type of equipment. Average speed is between 20 and 30 mph. Two factors combine to keep the average speed relatively low--close station spacing (0.64 mile, average) and the nature of the right-of-way. Four lines operate, for at least some portion of their route, on the elevated tracks of the Loop El. This structure, which dates from the turn of the century, has extremely sharp turns (90-ft. radius) that must be negotiated at low speed. The Loop El is also a congested part of the system; the four lines using it operate on a composite headway of about 1 minute at peak periods.

Including originating passengers and transfers from bus routes, the CTA rail rapid transit system carried a total of 126.8 million passengers in 1973 and an estimated 129.2 million in 1974. The average length of a passenger trip is about 7.9 miles or 16 minutes (compared to 15.5 miles and 22 minutes in BART). The average passenger fare is roughly 28 cents per ride.

ATC Features

The train control system in CTA has undergone extensive change since the property was acquired from the Chicago Rapid Transit Company in 1947. At that time, trains were operated almost completely under manual control by the motorman using visual observation and compliance with rules to regulate speed, station stopping, and following distance behind other trains. Color-light wayside block signals existed over about 10 percent of the trackage, mainly on curves and in the subways. Wayside signals with trip stops for train protection were installed only in the State Street subway (about 10 track-miles). In all other areas, the motorman had no display of information in the cab or at the wayside, except signposts advising of speed limits on curves or downgrades. The train crew consisted of a motorman, a conductor, and sufficient guards to man the doors, collect fares, and provide passenger information. Only a few cars had door controls sufficiently sophisticated to permit a trainman to operate the door at the far end of a car, so that trains required a crew of two to seven men, depending on length and type of cars,

Between 1947 and 1960, CTA installed wayside signals with trip stops in the remaining portions of the subway lines and some of their extensions. The elevated lines in the Loop, however, remained unsignaled; and train control was still essentially a manual operation accomplished by the motorman, with the assistance of towermen at interlocking.

In 1965, CTA began to install cab signaling, first on the Lake portion of what is now the West-South line and then the new Dan Ryan and Kennedy extensions, which were opened for service in 1969 and 1970, respectively. By 1974 the conversion to cab signaling was completed on the West-Northwest and North-South lines, The remaining lines—Skokie Swift, Ravenswood, and Evanston (including the Loop El)--are scheduled for conversion in early 1976, At the completion of the project, about 75 percent of the system will be cab signaled, and the remainder will be protected by stop-enforcing wayside signals.

With the installation of cab signaling, CTA has gone from the almost completely manual system to a semiautomated form of operation, Train separation and overspeed protection are automatic. Train operation is manual, but with machine-aiding of the motorman by means of the cab display unit. Supervision of trains (schedule maintenance, traffic monitoring, and routing) are essentially manual operations accomplished by dispatchers in central control or by towermen at interlocking, with some remote control and automatic interlocking.

Except for the Skokie Swift and off-peak Evanston shuttle trains, which are manned by a single operator, all CTA trains have a two-man crew, The motorman operates the train from the cab and controls all movement. The conductor, stationed at least one car length to the rear of the motorman, controls the opening and closing of doors at stations and makes passenger information announcements. At certain stations, during off-peak hours when collection booths are closed, the conductor also receives fares.

Thus, the human operator (especially the motorman) plays an indispensable role in the CTA system. Except for train protection and speed limit enforcement performed by wayside or cab signaling, the motorman controls the operation of the train, The skill with which propulsion and braking

G RE —C A h W N hw R h M d h K d E p w

FIGURE 30.—Interior View of CTA Train (Note conductor at rear of car.)

are handled determine the smoothness of the ride, the precision of station stops, the adherence to schedule, and the response to incursions on the right-of-way.

Problems and Issues

The basic problems facing CTA are typical of the mature rail rapid transit systems in this country. The right-of-way, structures, rolling stock, and signals are in need of modernization or replacement, There is also a need to expand the service in response to the growth and extension of the metropolitan area, Paradoxically, however, the patronage of CTA has been declining in recent years. The ridership for the combined bus and rail system in 1973 was off about 24 percent (about 188 million passengers) from that of 1966, a drop of roughly 3 percent per year.[27] The figures for 1974 show an upturn (30 million), which may indicate a switch by the public away from the automobile as a result of a growing concern with energy usage and conservation of resources. While the revenues from transit operations have generally declined, the costs have risen. This has created mounting operating deficits, which amounted to $22.1 million for CTA in 1973, despite nearly $37 million in emergency grants from State, county, and municipal funds. CTA thus finds itself in a position where it must expand and improve the system to meet public needs, but with a shortage of farebox resources to do so.

The conversion to cab signaling was motivated by more than a desire to modernize the system and thereby attract more patrons. There was also a fundamental concern with the safety of a system which offered only a very limited level of signal protection. Operation of trains on rather close headways by means of visual reference and procedural separation created safety problems. CTA has had an inten-

[27] Includes originating and transfer passengers.

sive safety training and awareness program since 1954. While this has resulted in a steady and heartening decline of 40 percent in. the traffic and passenger accident rate over 20 years, the problems of collisions and derailments persisted, Between 1964 and 1974 there were 35 collisions between trains which resulted in injuries and 48 derailments (only seven of which produced passenger injuries). This amounted to eight mishaps per year, or one about every 6 weeks.

Human operator error was determined to be a causal factor in every collision, Typically, the motorman either failed to observe a train ahead, did not maintain the proper following distance, or misjudged the stopping distance. In derailments, about half of the accidents were also caused by human error or improper operation (most commonly switching mishaps or overspeed on curves), The installation of a modern cab signaling system was seen by CTA as the way to prevent these types of accidents. On theoretical grounds, this would appear to be a very effective measure, but it is still too early to draw any firm conclusions from CTA operating experience since the conversion to cab signals.

The cab signaling program has brought with it certain new operational problems. The reliability of the new equipment, particularly during the transitional period, has been rather low. CTA engineers have found that the installation and debugging process takes several months: but, when completed, cab signals do not pose an inordinate maintenance problem from the point of view of equipment reliability,

Another aspect of cab signal conversion which represents a problem is in the area of human factors. Installation, checkout, and servicing of the equipment calls for new skills in maintenance personnel. CTA has encountered a shortage of qualified signal maintainers and has had to undertake an extensive training (and retraining) program for shop personnel, Train operators, too, have had to be instructed in the use of the cab equipment, and there is some anecdotal evidence that the process of learning to run the train in this new mode of operation is taking longer than expected.

The long-range program for CTA involves two major undertakings in the area of train control. First is the replacement of the antiquated Loop El with a modern subway system. A part of this project will be installation of a cab signaling system for all underground lines in the downtown area. The second project will involve the incorporation of more automation in train supervisory and dispatching functions. This includes installation of a modern model board in central control and computer aid for schedule maintenance and adjustment.

FIGURE 31.—Lake-Dan Ryan Train Entering the Loop

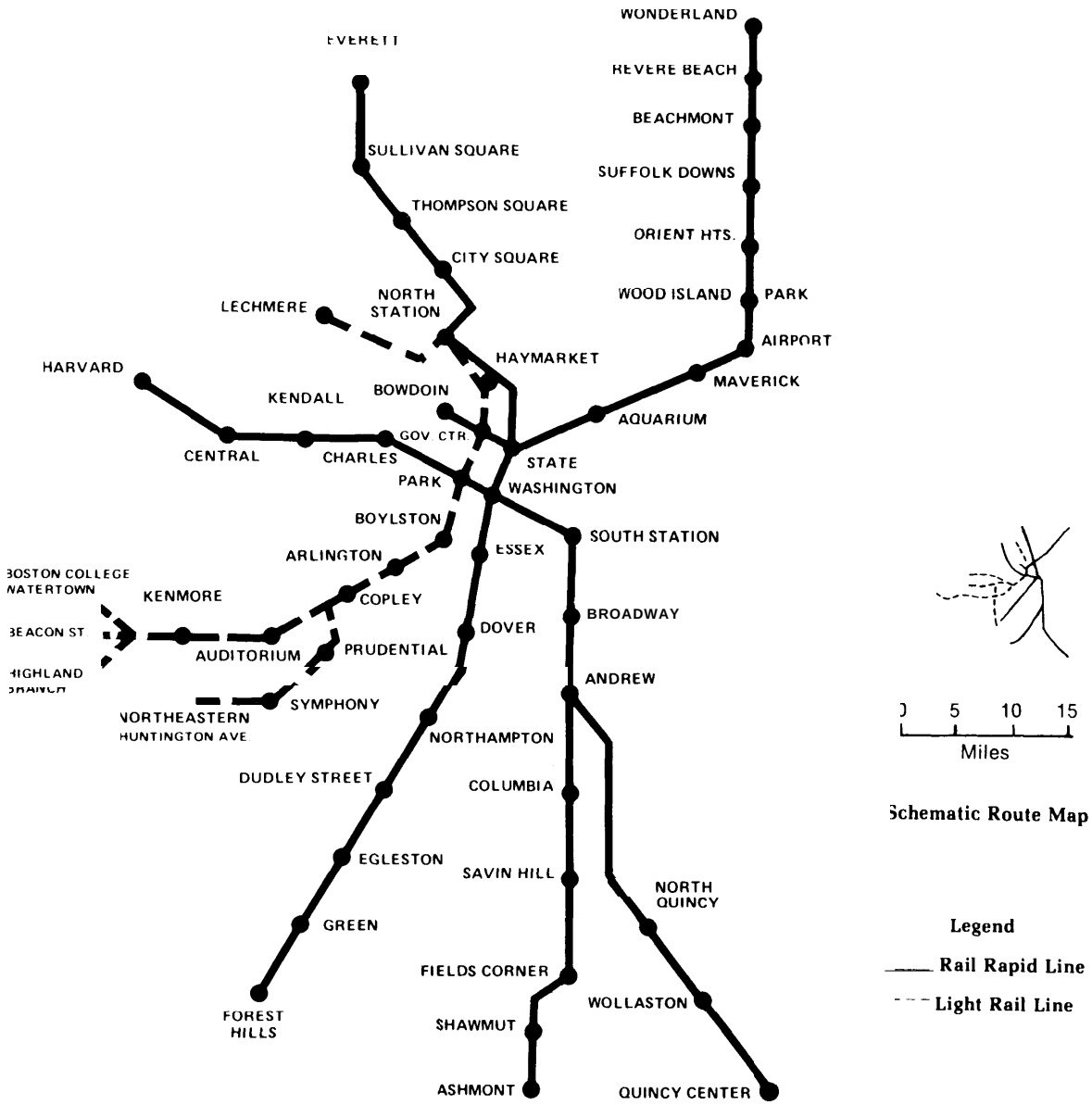


FIGURE 32.—MBTA Route Map

System Characteristics

MBTA, serving the metropolitan area of Boston, is one of the oldest rail rapid transit systems in the United States. Service on the first line, now a part of the Orange Line, began in 1901. MBTA is an integrated rail and bus system, the rail portion consisting of three rapid transit lines (designated Red, Orange, and Blue) and a trolley (light rail) line known as the Green Line (shown as a dashed line in the route map). Only the three rail rapid transit lines are considered in this report.

The MBTA lines comprise 30 route miles, of which a little over half (16 miles) are on protected surface right-of-way. Of the remainder, 10 miles of

TABLE 4.—MBTA System Facts

ROUTE MILES	Surface	16
	Elevated	4
	subway	10
		3 0
STATIONS	Number	43
	Avg. Spacing (mi.)	0.7
VEHICLES	Number	354
	Weight (tons)	22–35
	Length (ft.)	48–70
	Capacity (psgrs.)[1]	125–250
	Av. Age (yrs.)	18
CAR MILES	(mill. /yr.)	10.3

TRAIN LENGTH (cars)	Max.	4
	Min.	2
SPEED (mph)	Max.	[2]50
	Av.	[3]20
SCHEDULED MINIMUM HEADWAY (min.)		2 1/2
MANNING	No. in Train Crew	[4]2– 3
	O&M Employees/Cars	3.0
PASSENGERS	Annual (mill.)	85
	Av. Weekday (thou.)	283
TRAIN DEPARTURES PER DAY (each way)		590

MAIN LINE TRAIN CONTROL	
Train Protection	Mixture of cab signals with automatic overspeed protection and wayside signals with trip stops
Train Operation	Mixture of manual operation and automatic speed regulation
Train Supervision	Mixture of centralized and local manual control

(1974 Data)

[1]Full (complement of seated passengers plus standees in reasonable comfort; crush load is somewhat greater.
[2]Newer cars on the Red Line are capable of 70 mph but are governed to 50 mph.
[3]Average speed of new cars on the Red Line is about 30 mph.
[4]Train crew consists of motorman and one train guard (conductor) for each pair of cars.
[5]O& M (operations and maintenance) employees include O& M supervisors, but not station, administrative, engineering, planning and management personnel.

route are in subways, and 4 are on elevated structure. All trackage in the central business area of Boston is underground. MBTA has 43 stations (20 subway, 17 surface, 6 elevated), with an average spacing of about 0.7 mile.

A distinguishing feature of the system is the age and diversity of the rolling stock. Five different types of cars are in operation. The cars on the Blue Linte are oldest. consisting of 40 cars dating from 1923 and 48 from 1953. They weight 44,000 and 46,000 pounds, respectively, and are 48 and 49 feet in length. Orange Line cars are 17 years old, weigh 58,000 pounds, and have an overall length of 55 feet. The Red Line has the newest equipment--90 so-called "Bluebirds" acquired in 1963 and 76 "Silverbirds" acquired in 1970. Both types are 70 feet long. The Silverbirds weigh 64,000 pounds, and the older Bluebirds 70,000 pounds. All cars are operated as married pairs in consists of two or four. Some of the Red Line Silverbirds are capable of single-car operation, but they are not so used at the prsent time.

Because there is no connecting trackage and common yards and because of varying platform heights and car widths, cars cannot be exchanged between lines, In effect, MBTA operates as a system with three separate parts, linked only by passenger transfer stations where routes intersect. One consequence of this arrangement is a fleet with a relatively high proportion of reserve cars—about 150 in a fleet of 354, or 43 percent.

Another distinguishing feature of MBTA is the composition of the train crew which, in addition to the motorman, is made up of one train guard (conductor) for each pair of cars. The rush hour consist of four cars thus requires a crew of three. The train

guards are stationed either on a platform between each pair of cars or inside at the rear of each pair of cars and are responsible for door operation. The origin of this manning formula is obscure, but it is reputed to be a safety measure for emergencies or breakdowns, where the train guards could help evacuate passengers. It may also be a carryover from the time when sophisticated door operating equipment was not available, and a pair of cars was all that one person could handle. Whatever the origin, this manning formula is now a part of the contract with the labor union and has not been changed even though all MBTA cars are equipped with doors that can be operated by one man regardless of train length.

R MB O

FIGURE 34.—Red Line Train Arriving at Wollaston Station

Depending on the type of car, the maximum design train speed is between 30–70 mph—the newer equipment having the greater top speed, However, because of close station spacing and Massachusetts Department of Public Utilities safety rules, train speed is governed to 30 mph on the Blue Line, 35 mph on the Orange Line, and 50 mph on the Red Line. Average line speed (including station stops) is between 20 and 28 mph. Trains are operated on headways of 2 1/2 to 3 1/2 minutes in peak periods and 4 1/2 to 9 minutes in the base period.

In 1974, MBTA carried a total of 85 million passengers. Average weekday patronage was approximately 283,000, including bus and light rail transfer passengers. The typical passenger trip is about 3.1 miles in length and consumes a little less than 8 minutes.

ATC Features

MBTA has only a minimal level of train control automation. Most of the system (all but the Andrew-Quincy Center branch of the Red Line) has wayside signals and trip stops for train in separation and automatic interlocking contro1 but no other ATC features. Since 1971, the Andrew-Quincy Center (or South Shore) branch of the Red Line has been equipped for cab signals. However, the Massachusetts Department of Public Utilities has not yet authorized cab signal operation because of questions as to the safety of the installation, As an interim measure. Red Line trains are run on a "manual block" system with one-station separation between trains. Under this procedure, a following train may not leave a station until a radio message has been received from a dispatcher that the leading train has departed,

Train operation (speed regulation, station stops, and door control) is manual, except for Silverbird cars, which are equipped with automatic speed regulation. There is some machine-aiding of the motorman in running the train, in the form of slip-slide control (for Silverbirds only).

Train supervision is essentially manual, except for automatic train dispatching devices, Train progress is monitored by personnel at central control by means of three separate train boards (one for each line), activated by track circuits. Contact with individual trains and with wayside and station personnel is maintained from central control by voice radio. Except for a few locations equipped with automatic interlocking to control train turnaround at terminals, all route assignment functions are performed manually.

Problems and Issues

MBTA is an old system in the process of modernization and transition. Rolling stock on the Orange and Blue Lines is approaching the end of its service life and will be replaced with the help of a recently received $70 million grant from UMTA. Track, way, and structures in older parts of the system are being refurbished, and extensions of the lines are under construction or in the planning stage.[28] The power generation and distribution system[29] is antiquated and no longer adequate to meet demand. A long-range program of replacement is underway.

Like other parts of MBTA, the signal and train control system is undergoing modernization. Here, the situation is much like that in CTA a few years ago at the start of their cab signal conversion program, There is wayside signal and trip stop protection on most lines and the beginnings of a conversion to cab signaling on two extensions (the Red Line Quincy branch and the Orange Line Wollaston extension). The remainder of the Red Line is scheduled for conversion to cab signaling, and the new cars for the Orange and Blue Lines will be equipped with cab signal equipment to permit eventual conversion of these lines too,

The Red Line cab signal installation has had several problems, The Massachusetts Department of Public Utilities has not yet certified the safety of the installation, DPU concern centers in two areas: the reliability of the equipment and the possibility of incorrect speed commands. Pending DPU approval, the Red Line has been operating under a manual block system (in effect, without cab signals) since 1971,

The operational experience with cab signals has been disappointing. In addition to problems of reliability, there have been maintenance difficulties. Shop facilities have not been adequate.[30] Spare parts are in short supply. There has been insufficient funding for maintenance work, with the result that not enough repairmen can be hired. Cab signal equipment tends to need maintenance more often and to require more maintenance time than other kinds of transit equipment. MBTA maintenance supervisors estimate that a major part of the maintenance effort is devoted to repairing breakdowns, with the result that preventive maintenance and overhaul must be somewhat slighted.

A complicating factor in the maintenance situation is the shortage of qualified maintenance personnel, Union rules permit transportation department employees (motormen and train guards) with seniority to bid for openings in car shop jobs without regard for work skills and experience. The limited funding available for maintenance does not allow a complete formal training program for such personnel, who must receive much of their training on the job by informal methods. This has not proven to be an effective way to develop the skills needed for maintenance of sophisticated electronic equipment.

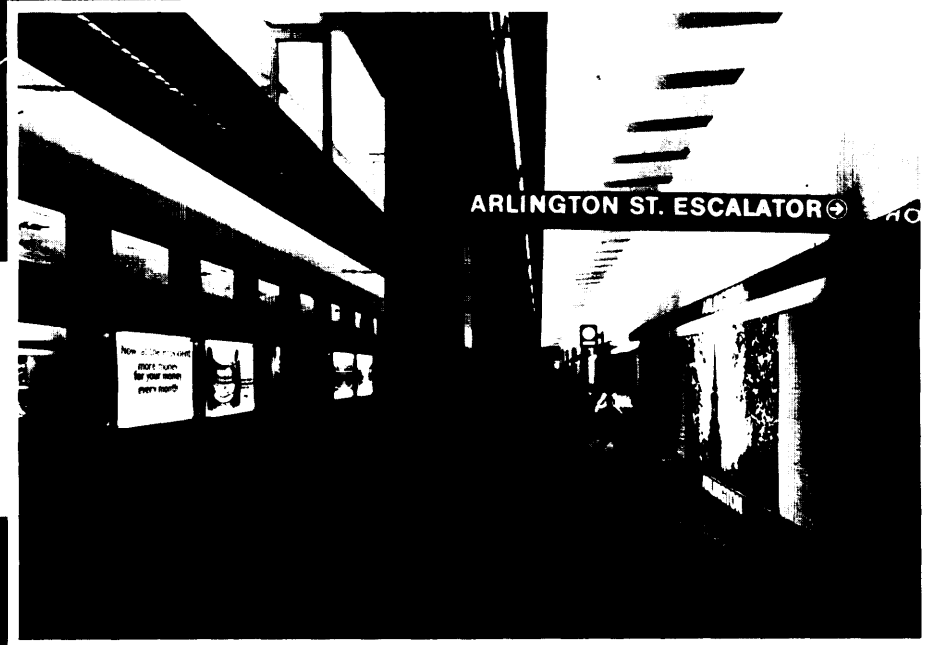
The problems of MBTA are typical of a system in transition to a new form of technology. Installation and checkout of new equipment disrupts the established pattern of operation and maintenance. The new equipment must be integrated with the existing system. Debugging is a troublesome process. Learning to make effective use of the equipment takes time and places demands on the labor force to adapt to new procedures and techniques. The entire system must find a new equilibrium. MBTA, like other older transit systems, is finding that the process of incorporating new technology is not always smooth and trouble-free.

[28] The Wellington extension of the Orange Line opened for service in September 1975.

[29] MBTA, unlike other transit systems, still generates much of its propulsion power (25 Hz a.c.). New lines and most stations, however, run on 60 Hz a.c. power purchased from local utility companies.

[30] MBTA is currently building three modern rail transit maintenance facilities, the first two of which (for the Red Line and the Orange Line extension) were dedicated in 1975.

Tower C, at one time the busiest control and interlocking tower in the MBTA system, now replaced by a modern automated facility.



Remodeled Arlington St. Station.

Construction of the new Community College Station on the Orange Line Extension. (Overhead is Interstate Highway I-93.)

FIGURE 35.—The Old and The New

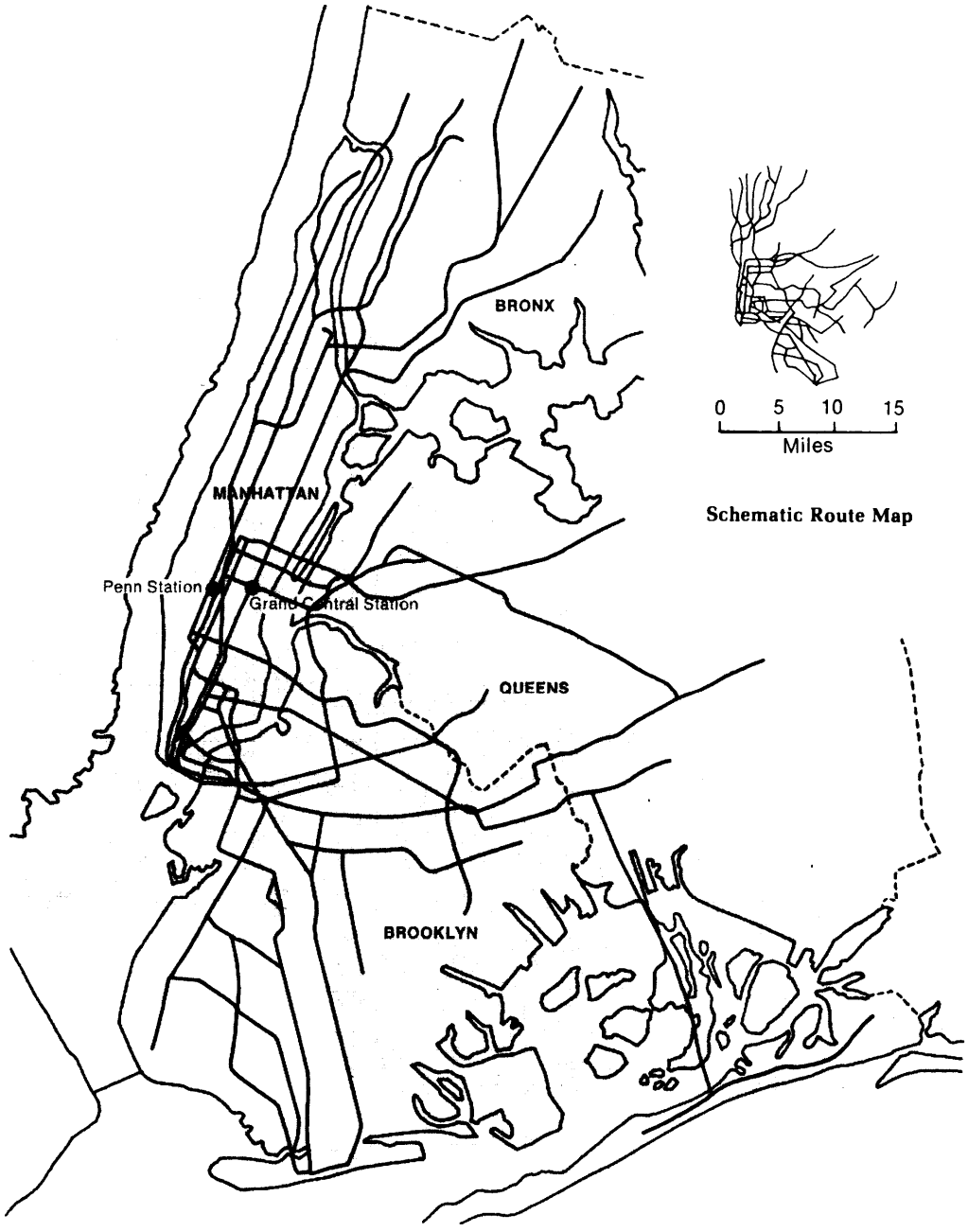


FIGURE 36.—NYCTA Route Map

System Characteristics

NYCTA is the largest and most complex rail rapid transit system in the United States. NYCTA has more route-miles than BART, CTA, MBTA, and PATCO combined; and it has approximately half of the total rail rapid transit track-miles in the country. On an average weekday NYCTA carries more passengers than the total population of Chicago. Of the roughly 2 billion rail rapid transit passengers in the United States each year, half are NYCTA patrons. NYCTA has almost 29,500

TABLE 5.—NYCTA System Facts

ROUTE MILES	Surface	23
	Elevated	72
	Subway	137
		232
STATIONS	Number	463
	Avg. Spacing (mi.)	0.5
VEHICLES	Number	16,681
	Weight (tons)	34–43
	Length (ft.)	51–75
	Capacity (psgrs.)[2]	136–204
	Av. Age (yrs.)	17
CAR MILES	(mil1./yr.)	320.6

TRAIN LENGTH (cars)	Max.	11
	Min.	2
SPEED (mph)	Max.	50
	Av.	[3]20
SCHEDULED MINIMUM HEADWAY (min.)		1 1/2
MANNING	No. in Train Crew	2
	O&M Employees/Car[4]	3.1
PASSENGERS	Annual (mill.)	1,0!36
	Av. Weekday (thou.)	3,740
TRAIN DEPARTURES PER DAY (each way)		8,000

MAIN LINE TRAIN CONTROL

Train Protection	Wayside signals with trip stops
Train Operation	Manual operations
Train Supervision	Mixture of centralized and local manual control

(1974/75 Data)

1 Does not include 754 new R–46 cars now being delivered.

2 Full complement of seated passengers plus standees in reasonable comfort; crush load is somewhat greater.

3 Local service; express service averages about 28 mph.

4 O&M (operations and maintenance) employees include O&M supervisors, but not station, administrative, engineering. planning and management personnel,

') The newer R —44 and R —46 series cars are equipped for automatic speed regulation and programed station stopping in anticipation of use on planned or new lines and extensions.

employees,[31] not counting the 5,100 transit police who constitute the eighth largest police force in the United States. The annual operating budget for NYCTA in 1974–75 ($951 million) is equivalent to 10 percent of that of the entire U.S. Department of Transportation for FY 1975 and only slightly less than the DOT funds budgeted for all of mass transit and railroads in the same period ($965 million).

The complexity and density of the NYCTA network can be appreciated by comparing the schematic route map above with those of other systems. The geographic area served by NYCTA is roughly 15 x 20 miles, which is only slightly larger than the CTA area but less than half that covered by BART. Within this area, however, NYCTA operates 29 routes (26 regular, 3 shuttle) as compared to 7 in CTA and 4 in BART. Expressed as the ratio of route-miles to area served, NYCTA has 0.77 miles of transit route per square mile; CTA and MBTA have 0.36; and BART has 0.09. In other words, the NYCTA network is about twice as dense as CTA and MBTA and eight times denser than BART. Density alone, however, does not account for the whole difference between NYCTA and other systems since the complexity of the system increases exponentially as a function of the number of lines on common tracks. In NYCTA virtually all the lines in Manhattan and Brooklyn share track with at least one and as many as three other lines.

The NYCTA system is made up of two operating divisions—Division A (the former IRT lines) and

31 NYCTA also employs about 8,600 in bus operations, making a total workforce of 38,066 (43,167 including police).

Division B (the former BMT and IND lines)[32]—comprising 232 miles of route. Over half of the route-miles are in subways (127 miles). There are 72 miles of elevated route and 23 miles on protected surface right-of-way. NYCTA has 463 stations (265 subway, 160 elevated, 38 surface), with an average spacing of 0.5 mile.[33]

The fleet consists of 28 different types of cars, ranging in age from R–1 series (1930) to the R–46 series acquired in 1975. The newest equipment (300 R–44 cars and 754 R–46 cars) is 75 feet in length and weighs 80,000 and 86,000 pounds, respectively. Older equipment (the R–38 to R–42 series) is 60 feet long and weighs 68,000 to 74,000 pounds. There are also about 1,600 51-foot cars acquired in 1946–58. The total fleet now numbers 6,681 and will grow somewhat when delivery of the R–46 series is completed and older equipment is phased out.

Platform length and operating practice govern the size of the peak period consist, which is eight 75-feet cars, ten 60-feet cars, or eleven 51-feet cars. The maximum operating speed of trains is 50 mph. The average line speed (including station stops) is 18.5 mph for local service and about 28 mph for express trains. Minimum peak period headway on an individual line is scheduled at 2 minutes, but the signal system is designed for 90-second headways. The composite headway at some interlocking may be as short as 50–60 seconds.

In fiscal year 1973–74, NYCTA carried 1,096 million passengers for a total of 5,480 million passenger-miles. Average weekday ridership was about 3.7 million. Only slightly more than half of these riders (53 percent) were carried in the rush hours.[34] This suggests a unique pattern of ridership for NYCTA in comparison with other U.S. systems, New Yorkers tend to use the NYCTA throughout the day (not just for trips to and from work) and for short trips. The average trip length is estimated to be slightly over 5 miles and to take about 17 minutes.[35]

[32] IRT—Interborough Rapid Transit, BMT—Brooklyn Manhattan Transit, IND—Independent.

[33] This is spacing between local stations. The spacing of express stations is greater, on the order of 1 mile,

[34] In other systems, peak-period ridership customarily accounts for about two-thirds of the daily traffic.

[35] Trip length is also partially a function of the compactness of the boroughs of Manhattan and Brooklyn where most trips occur.

ATC Features

NYCTA has a relatively low level of automation. Train protection (train separation and interlocking control) is accomplished automatically by wayside signals with trip stops to prevent block violation. Some portions of the system (principally curves and grades in the subways) also have time signals and trip stops for overspeed protection, but elsewhere this function is accomplished manually by the motorman using operating rules and posted civil speed limits.

Train operation is manual. The crew is two (motorman and conductor), regardless of train length. The train is under the control of the motorman who regulates speed by estimation. (There is no speedometer in the cab except for the new R–44 and R–46 cars,) Station stopping and door control are manual operations-the former by the motorman, the latter by the conductor.

Except for automatic train dispatching equipment, automatic train identity systems, and some automatic interlocking, train supervision is manual, Scheduling, route assignment (except at automatic interlocking), and performance monitoring are performed by supervisory personnel at central control and by towerman at remote locations. Train supervision is somewhat more decentralized in NYCTA than in other systems, primarily because the size and complexity of the system make central control by manual means impractical. ‘Automated train identification equipment is used in some locations, but for most of the system this function is performed by manual methods. Computer-assisted maintenance scheduling and record keeping is employed. Equipment for automatic recorded passenger information announcements is installed at some stations, primarily major transfer points.

Problems and Issues

NYCTA has embarked upon an ambitious program of modernization and expansion, More than 1,800 new cars have been delivered or are on order. New lines to ease the congestion in heavily traveled corridors are in the planning stage. These new lines, notably the proposed Second Avenue line, will have cab-signaled ATP and ATO. It is also planned to upgrade train control on existing lines over a 20-year period by converting to cab-signaled ATP, Another part of this modernization program, already in progress, is installation of a centralized

FIGURE 37.—IND F Train on Elevated Line in Brooklyn

M

R–16 BMT-IND (1953)

R–36 IRT (1962)

R–44 BMT-IND (1970)

FIGURE 38.—Examples of NYCTA Transit Cars

communication center for train supervision at NYCTA headquarters in Brooklyn. A new two-way train radio and police communications system has recently been completed.

Continuing, and worsening, deficits in transit operations have recently been forced a cutback in the program. Funds intended for system improvement have had to be siphoned off to meet operating expenses. The financial crisis of New York City as a whole has also had an impact on NYCTA, forcing even further curtailments in the planned new transit lines and procurement of replacement equipment.

The new R–44 and R–46 series cars are equipped with cab signal units; but since the associated track and wayside equipment has not yet been installed, trains are run with cab signals deactivated, relying on wayside signal and trip stop protection. The maintenance and reliability problems that have been encountered with the R–44 cars and with the recently delivered R–46 cars are thus not ATC problems, and there is no way of estimating what influence the ATP and ATO equipment of these cars may have on car availability.

The gravest maintenance problem for the NYCTA has nothing to do with ATC as such, but does influence the ability of the shop force to keep train control equipment running. The NYCTA has been stricken with an epidemic of vandalism. The most obvious form is graffiti, which completely covers the outside and inside of cars. Officials estimate that 95 percent of the cars are defaced on the outside and 80 percent on the inside. There is also extensive breakage of windows, safety equipment, train radios, and motorman consoles. The vandalism even extends to yards and track equipment. The Flushing line averages 40 broken windows a day, and 70 or more trains are vandalized (and often rendered unserviceable) on the BMT each week, The funds and maintenance force that must be committed to coping with the damage are of such magnitude that other forms of corrective and preventive maintenance suffer.

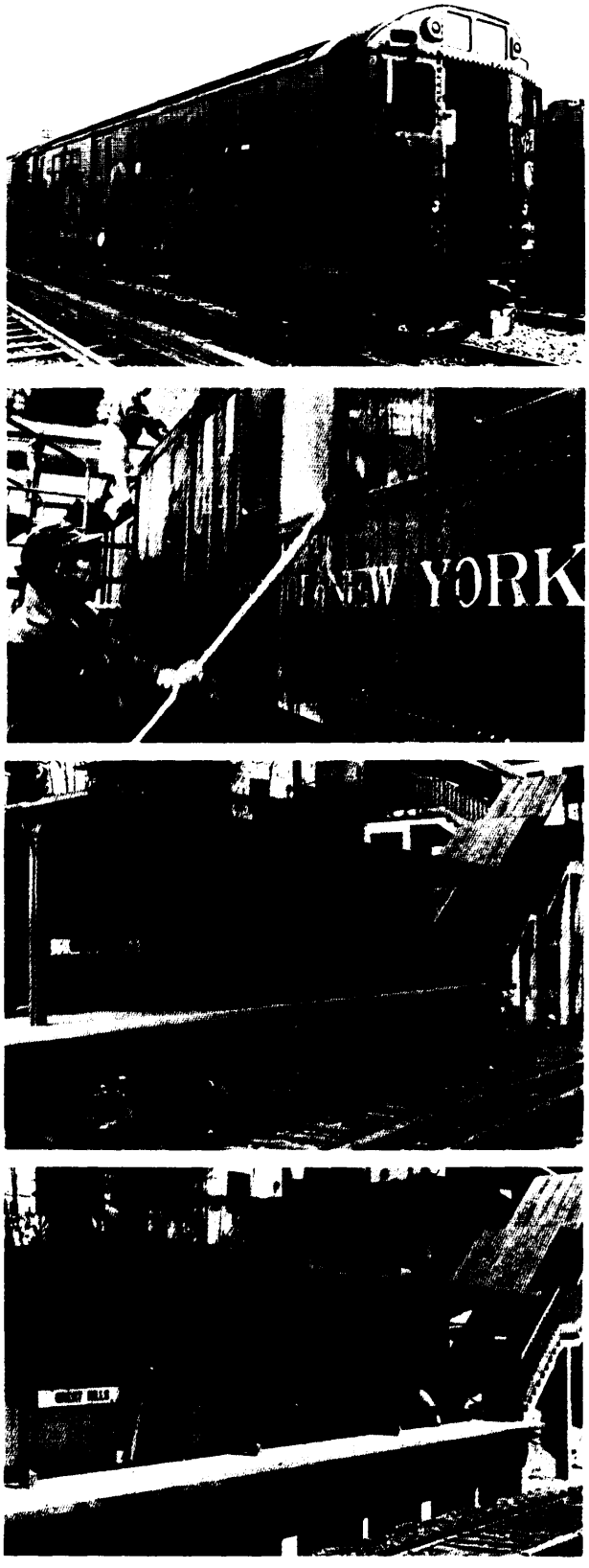


FIGURE 39.—The Graffiti Epidemic

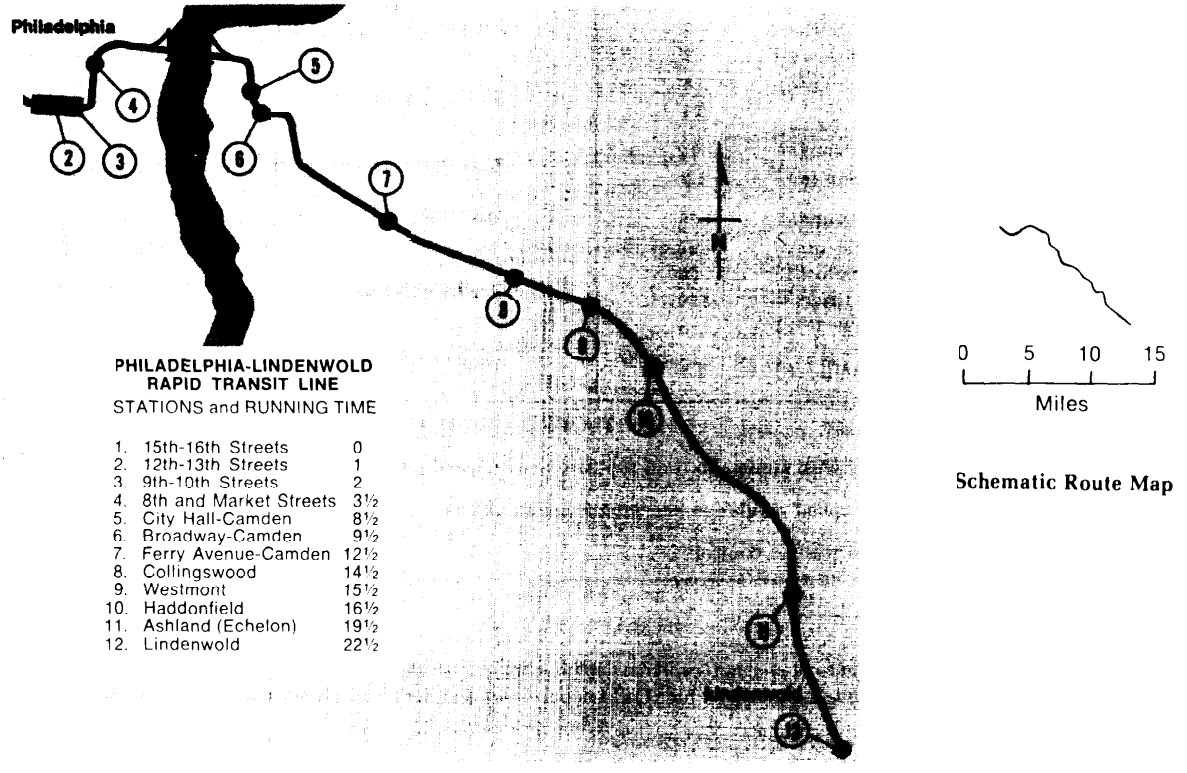


FIGURE 40.—PATCO Route Map

System Characteristics

PATCO, also known as the Lindenwold Hi-Speed Line, consists of a single route connecting seven southern New Jersey suburban communities with the city of Philadelphia, PATCO is a hybrid system, resembling a commuter railroad in suburban New Jersey and a subway transit system in downtown Camden and Philadelphia, The Camden-Lindenwold segment of the line was opened for operation in January 1969; through service to Philadelphia over the Benjamin Franklin Bridge began a month later. The line is owned by a New Jersey -Pennsylvania bi-State agency, the Delaware River Port Authority (DRPA).

Like BART, PATCO was planned and built as an alternative to another automobile bridge or tunnel to link the growing suburbs and a central business area separated by a body of water.[36] The evidence accumulated in its 6-year history suggests that PATCO has been successful in winning the patronage of the automobile driver. Surveys have shown that about 40 percent of PATCO patrons are former motorists. It has also been established that PATCO now carries about 30 percent of all daily commuter trips between South Jersey and center-city Philadelphia. A side benefit is that PATCO has served to reduce traffic congestion on parallel highway arteries. For instance, the average rush hour speed on White Horse Pike (running alongside the PATCO line) increased by 30 percent from 1960 to

[36]Unlike BART, however, PATCO did not involve building a separate water crossing, PATCO trains run on right-of-way of the former Camden-Philadelphia Bridge line on the Benjamin Franklin Bridge.

TABLE 6.—PATCO System Facts

ROUTE MILES	Surface	9
	Elevated	1
	Subway	4
		14
STATIONS	Number	12
	Avg. Spacing (mi.)	1.2
VEHICLES	Number	75
	Weight (tons)	39
	Length (ft.)	68
	Capacity (psgrs.)[1]	120
	Av. Age (yrs.)	6
CAR MILES	(mill./yr.)	4.3
TRAIN LENGTH (cars)	Max.	6
	Min.	1
SPEED (mph)	Max.	75
	Av.	40
SCHEDULED MINIMUM HEADWAY (min.)		2
MANNING	No, in Train Crew	1
	O&M Employees/Car[2]	2.7
PASSENGERS	Annual (mill.)	11.2
	Av. Weekday (thou.)	40
TRAIN DEPARTURES PER DAY (each way)		182

MAIN LINE TRAIN CONTROL

Train Protection	Cab signals with automatic train separation, overspeed protection, and interlocking control
Train Operation	Automatic speed regulation and programed station stopping
Train Supervision	Centralized manual control

(1974 Data)

[1] Full complement of seated passengers plus standees in reasonable comfort; crush load is somewhat greater.

[2] O&M (operations and maintenance) employees include O&M supervisors, but not station, administrative. engineering, planning and management personnel.

1970, primarily as a result of the start-up of rail rapid transit service.

The PATCO line is approximately 14 miles long (9 miles on surface right-of-way or in cuts, 1 mile on elevated structure, and 4 miles of subways in Camden and Philadelphia). There are 12 stations (6 elevated or surface and 6 subway), with an average spacing of 1.2 miles.

The car fleet is made up of 75 vehicles—25 married pairs and 25 singles. The married pairs are semipermanently coupled A-cars and B-cars, containing one set of train control equipment per pair, and may be operated from either end. The singles are double-ended cars, capable of independent operation or of running in trains with other singles or married pairs. The cars all weigh about 78,000 pounds and are 67.5 feet in length. Capacity, with standees, is about 120 passengers in the A-cars or B-Bears and slightly less in the singles, because of the two operator cabs. Six-car trains are run in peak periods, two-car trains in base periods, and single cars nights and Sundays.

The cars are designed to run at 75 mph, a speed which is regularly attained on the suburban portions of the line. Maximum operating speed on the bridge and in tunnels is considerably lower (15–40 mph) because of grades and curvature. The average speed for an entire run, including station stops, is about 38 mph. Trains operate on 2-minute headways in peak periods.

In 1974, PATCO carried approximately 11.2 million passengers-over 40,000 on an average weekday, Total passenger-miles amounted to slightly over 95 million, The average trip, therefore, was 8.5 miles in length and took about 13 1/2 minutes. The average fare per passenger was 57 cents.

ATC Features

The PATCO train control system is a blend of manual and automatic operation. The design philosophy reflects two basic principles. First, the design of the system made use of technology that, at the time, represented the best of available, proven equipment. Technological innovation (and risk) at the component and subsystem level was held to a minimum. The combination and integration of elements, however, resulted in a system of highly advanced character. Second, the human operator was to be fully integrated into the system, such that he could act as a back-up to automated equipment and as the means of enhancing system performance in response to unusual conditions.

All train protection (ATP) functions are automated, accomplished by a mixture of carborne, wayside, and track equipment. Train operation (ATO) is also automatic, with two important exceptions. The single on-board operator (who is the equivalent of a motorman and a conductor) controls door opening and closing. The operator also controls train departure by pushing a start button on the cab console. Providing the doors are closed, this manual action initiates an automatic sequence of events in which the train accelerates (with automatic jerk limiting and slip-slide control), runs to the next station, decelerates, and brakes to a stop. Speed throughout the run is controlled to within +/-2 mph of command speed, and station stopping is with an accuracy of +/-50 feet.

Although train operation is normally automatic, it is also possible to operate under varying degrees of manual control (within the constraints of overspeed protection). This is often used in bad weather when the rails are slippery, especially on grades. The operator can order the train to bypass a station, without otherwise interfering with the automatic control process. The train can also be run in a completely manual mode (except for ATP). It is a procedural rule of PATCO that each train operator must run the train manually for an entire trip once a day in order to retain his operating skills. Thus, train control in PATCO can be characterized as an automatic system under supervision of an on-board operator who has the capability for manual intervention to compensate for malfunctions and to augment system performance.

In contrast, train supervision (ATS) is largely manual. PATCO uses dispatchers at a central train control board to oversee train movements. order schedule adjustments, and monitor overall system performance, Routing (switch control at interlocking) is automatic, but it can be overridden by central control. Communication with the train is by means of train phone, which uses the third rail as the conductor. Police, wayside maintenance personnel, and the Lindenwold car shop are linked with central control by a radio network.

FIGURE 41.—PATCO Train in Lindenwold Yard

72-683 O - 76 - 6

FIG(JRE 42,—Outbound on Ben Franklin Bridge

PATCO stations are entirely unattended, fares being collected by an automatic vending and gate system under closed-circuit television surveillance. One or two employees at central control oversee station activities by TV, make public address announcements, and handle calls for assistance from patrons by direct-line telephones at the fare gates.

Problems and Issues

The PATCO train control system has been singularly trouble-free, The engineers of the system attribute this to the design philosophy that made use of only proven elements and conventional technology. However, it is also true that the PATCO system is relatively simple, consisting of a single line without merging points and complex interlocking. The PATCO approach was not so ambitious as that of BART, to which it is often compared. While it can be said that PATCO accomplished its objectives more fully, it should also be noted that less was attempted. Still, the PATCO system is an admirable transit system engineering achievement, and it is widely publicized as an example of prudent and effective use of automation.

There appears to be no recurring reliability and maintenance problems associated with the ATC equipment in PATCO, Certain deficiencies of design and manufacturing quality control came to light during the initial year of operation, faulty wiring connections and termina1s being the most prevalen t. PATCO maintenance supervisors consider these to be no more than the usual start-up and debugging difficulties, even though it did take almost a year to wring the system out. In general, car availability has been excellent throughout the 6 years of operation, The number of cars needed to provide scheduled peak-hour service has been available 99.2 percent of the time or more each year, although this requires a two-shift maintenance activity that is not common in the transit industry, ATC equipment has not contributed a dlisproportionate share to the overall pattern of equipment failures and maintenance time.

In the initial planning of PATCO, it was proposed to build a three-branch system in New Jersey with a common trunk line over the bridge into Philadelphia. This plan was dropped in favor of the single-line system that was eventually built, Planning is now underway to build the two additional branches (to Mount Laurel and Glassboro) and to extend the existing Lindenwold line to Waterford-

FIGURE 43.—PATCO Train Operator Monitoring ATC Equipment

Berlin. This will result in a three-pronged route plan, very much like the BART system but somewhat smaller in scale. The junction of the three branches, equivalent to the Oakland Wye in BART, is a train control engineering problem of concern to PATCO, Experience with the existing system has shown that the PATCO ATC system is adequate for a single route. However, the level of automation (especially in the area of ATS) may not be sufficient to handle three routes merging and running on a single line over the Benjamin Franklin Bridge. In order to maintain the regularity and level of service now offered, it may be necessary to install more sophisticated and highly automated equipment to control interlocking and supervise traffic movement.

SYSTEMS UNDER DEVELOPMENT

There are three rail rapid transit systems now under construction—WMATA (Washington, D.C.), MARTA (Atlanta), and MTA (Baltimore). Of these, WMATA is nearest completion; the first 4.6-mile segment is scheduled to open with limited revenue service (7 a.m. to 7 p.m.) in the spring of 1976. Ground breaking for MARTA took place in February 1975, and initial service is planned for 1978–79, The Baltimore system is in the advanced planning stage and scheduled for completion in 1981 –82.

All three systems will employ advanced train control technology, at levels of automation in the range between the PATCO and BART systems. Table 7 is a summary of the ATC features planned or

TABLE 7. Automated Features of Three Transit Systems Under Development

ATC FUNCTIONS	WMATA	MARTA	MTA
ATP			
Train in Separation	Fully automatic	Fully automatic	Fully automatic
Overspeed Protection	Fully automatic	Fully automatic	Fully automatic
Route Interlocking	Fully automatic	Fully automatic	Fully automatic
A TO			
Velocity Regulation	Fully automatic, with alternative of manual operation	Fully automatic	Fully automatic
Programmed Stopping	Fully automatic, with alternative of manual operation	Fully automatic	Fully automatic
Door Control and Train Starting	Fully automatic, controlled by local timer subject to manual override	Fully automatic	Manual
ATS			
Dispatching and Monitoring	Console and display board supported by computer	Aided, hut not directly controlled, by computer	Centralized traffic control machine and automatic dispatching units
Performance Level Control	Four levels of run time between stations, w ith separate control of acceleration rate, dwell time, and skip-Stop	Computer modification of speed, acceleration, and dwell time, with manual override	Six levels of speed. set in by train opf'rater in response to visual signals at stations
COMMUNICATIONS			
Operator- Passengers	One-way PA and noise monitor system	one-way PA	One-way PA
Central Control–Passengers	One-way PA	One-way via train PA	One-way via train PA
operator-Central Control	Two-way radio phone	Two-way radio phone	Two-way radio phone

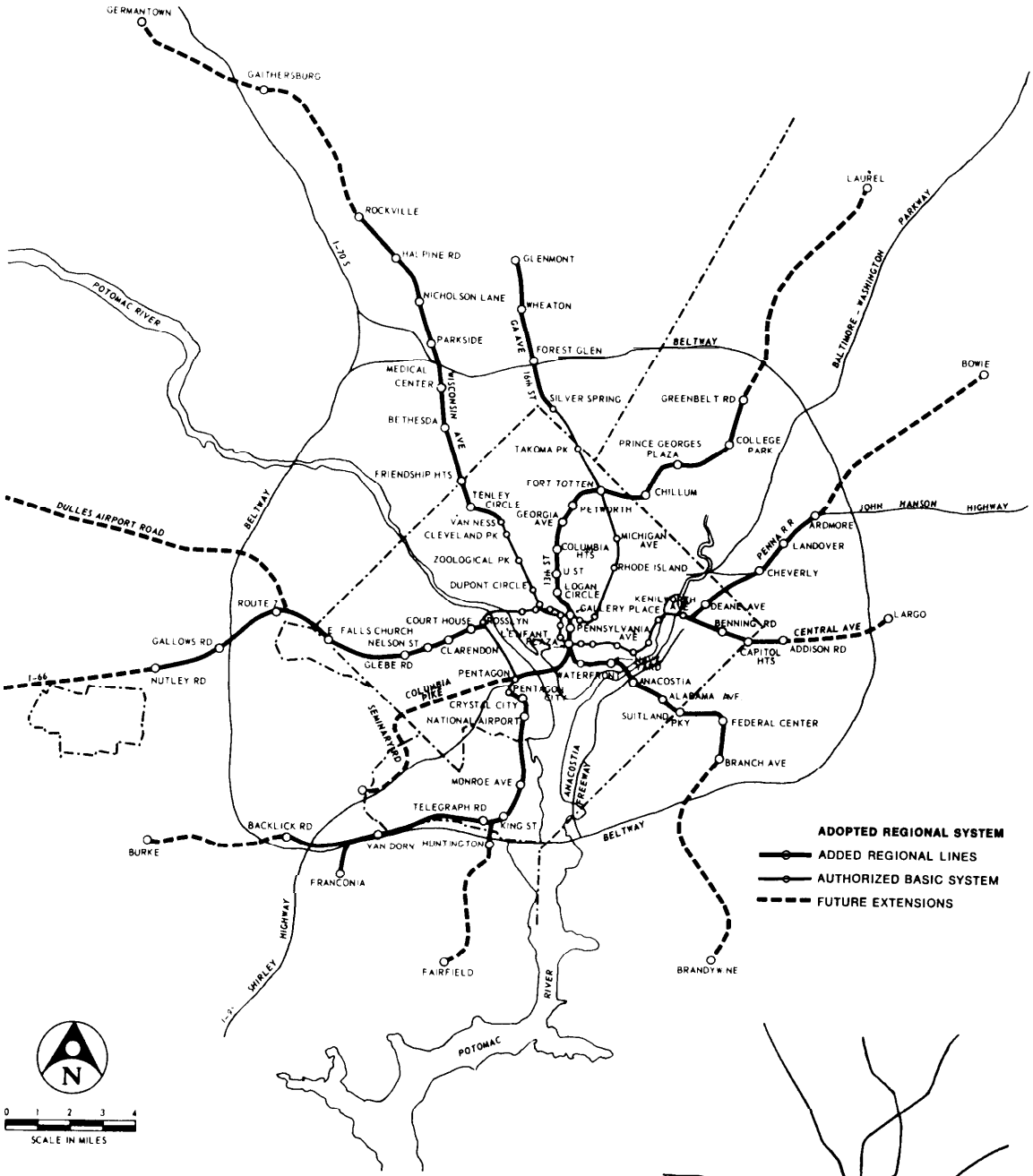
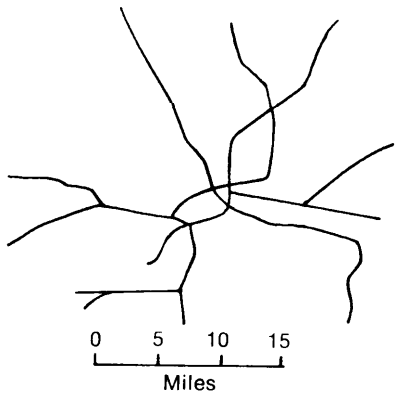


FIGURE 44.—WMATA Route Map



Schematic Route Map

proposed for each. Note that only the WMATA train control system is a firm design at this point; MARTA and MTA are tentative and subject to modification as the system evolves.

Washington Metropolitan Area Transit Authority (WMATA)

The WMATA Metro System is being built as a seven-phase project, with the last phase scheduled for completion in 1982.[37] At that time, WMATA will consist of 98 route-miles. serving 86 stations. There will be 47 route-miles underground, 42 miles at surface, and 9 miles on elevated structure. The WMATA system will serve the largest geographic area of any rail rapid transit system in the country (30 miles N-S and 35 miles E-W). However, the density of the network (route miles per square mile) will be rather low—about 0.09. which is the same as BART.

The WMATA fleet will be made up of 556 cars, 75 feet in length and weighing 72,000 pounds. Car capacity will be 175 (81 seated and 94 standees). The cars are designed to operate as semipermanently coupled A and B units (married pairs) to be run in consists of two to eight.

The train control system will have fully automatic train protection (ATP), including separation assurance, overspeed prevention, and route interlocking. The normal mode of train operation will be automatic (ATO), under the supervision of an on-board operator. Door closure, train starting, velocity regulation, programed station stopping, and door opening will be automated functions. Train operation will, therefore, be similar to the ATO system of BART, except that station dwell time will be under control of a local timing device in WMATA instead of a BART-like central computer. Unlike the BART system, however, the WMATA train operator will have several methods for intervening in the automatic operating process either to augment system performance or compensate for partial failures. In this regard, the WMATA train operation system will be similar to PATCO. Train supervision (ATS) will be computer assisted and will permit either manual or automatic adjustment of performance level, station stopping, and dwell time. In general, the WMATA approach to ATC has been to employ proven, existing hardware and advanced, but not revolutionary, technology.

[37] The first 4.8-mile segment was opened for service on March 27,1976.

Metropolitan Atlanta Rapid Transit Authority (MARTA)

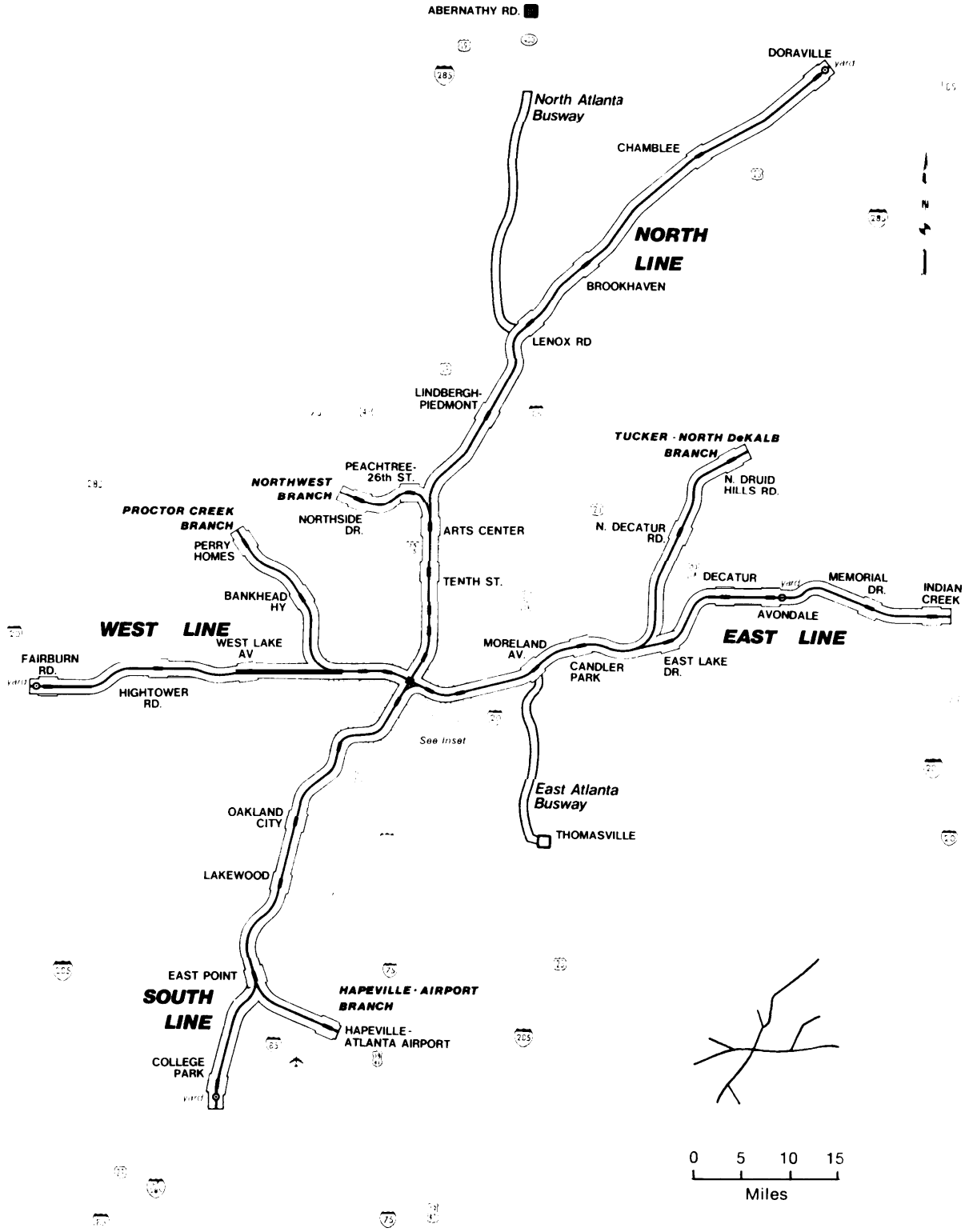
MARTA has recently begun construction of a 70-mile system of rail rapid transit integrated with high-speed busways, serving the Atlanta metropolitan area in De Kalb and Fulton Counties. The rail portion of the system will consist of approximately 50 route-miles, radiating from downtown Atlanta. The first segment (13.7 miles) is expected to be finished by 1980.

The MARTA fleet will have 200 cars, operating as married pairs in trains of up to eight. Speeds of up to 75 mph on 2-minute headways are proposed initially, with eventual reduction to 90-second headways in heavy demand corridors. The train will have one operator, who will monitor automatic train control equipment and provide limited manual back-up.

The train control system to be used in MARTA is still in the early stage of definition; a general functional design has been developed, but detailed engineering specifications had not been issued at the time this report was prepared. With regard to ATP and ATO, the MARTA system will be very much like BART.[38] Train protection and operation will be fully automatic, the on-board operator serving as a performance monitor. The operator will also be able to impose modifications of train operation functions. It is envisaged that the operator will act as a back-up to ATO equipment for emergency and degraded states of operation, but without the capability of running the train at full performance levels.

The supervisory functions carried out by central control will be aided extensively by a computer but will not be under direct computer control. A unique feature of the ATS system design is that it will be implemented in two stages. The first stage will provide for semiautomatic operation--computer-executed routing, dispatching, and monitoring in response to manual inputs and override by central personnel. The second stage will provide for automation of the routing and dispatching functions and will incorporate an Automatic Line Supervision (ALS) system for computer-controlled traffic regulation (dwell, performance level, schedule adjustment, reverse running, and station run-through). The implementation strategy is to use the

[36] MARTA has engaged the same general engineering consultant, Parsons Brinkerhoff-Tudor-Bechtel, who designed the BART system.



Schematic Route Map

FIGURE 45.—MARTA Route Map

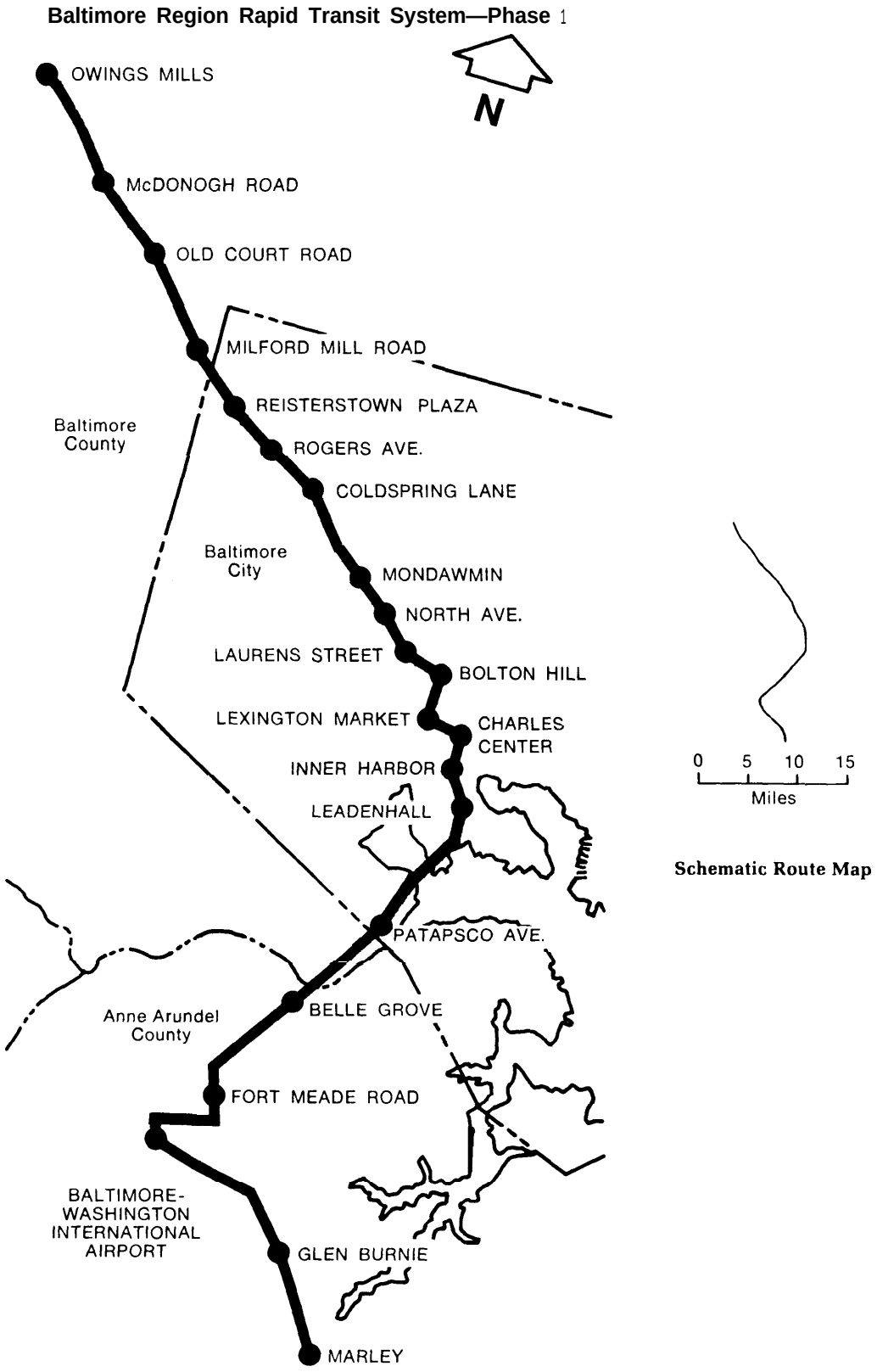


FIGURE 46.—Baltimore MTA Route Map

first, semiautomated stage as a baseline to get the system into operation and debugged and then to upgrade the central ATS complex to full automation when traffic demand increases. However, the first stage will be retained in an operable state, as a backup to automated central control for emergencies and nonnormal modes.

Mass Transit Administration of Maryland (MTA)

MTA in Baltimore is proposing to build a 28-mile rail rapid transit system extending from the northwest area of the city through downtown and terminating south of the Baltimore-Washington International Airport. So far, Federal grants have been advanced for only the northern half of the system; funding for the remainder is in question. Groundbreaking for construction of the northwest line was held in the fall of 1974.[39] Revenue service is scheduled to begin in 1981.

The ATC system for Baltimore has not progressed much beyond the preliminary design stage, The design concept calls for an automated system similar to BART in technology but with more direct involvement in train operation by an on-board attendant. ATP will be fully automatic, as in WMATA and MARTA, Train operation (ATO) will be automatic under normal conditions, except for door control and train starting, which will be manually initiated (like PATCO). There will also be provision for train operation at full performance levels in a semiautomated cab signal mode, A novel feature of the proposed ATC system is that the on-board operator will be able to set the train speed profile to any of six levels in response to commands from centraI control transmitted by visual signals at the stations. Train supervision (ATS) will incorporate several automated features, but the general level of automation of central control facilities will be somewhat lower than that of WMATA or MARTA,

A noteworthy aspect of the Baltimore system design is the requirement that it be compatible with WMATA, thus making it feasible to link up the two systems at some future time if demand and metropolitan area growth patterns so dictate, At this time, however, there is some question in the minds of the designers as to whether compatibility should be limited to physical characteristics (such as clearances, platform height, car size, and traction voltage) or whether it should also include the signaling and train control system.

[39] Concern over the cost of the proposed system led to a suspension of construction activity in the fall of 1975, pending a full review of costs and available sources of funding.