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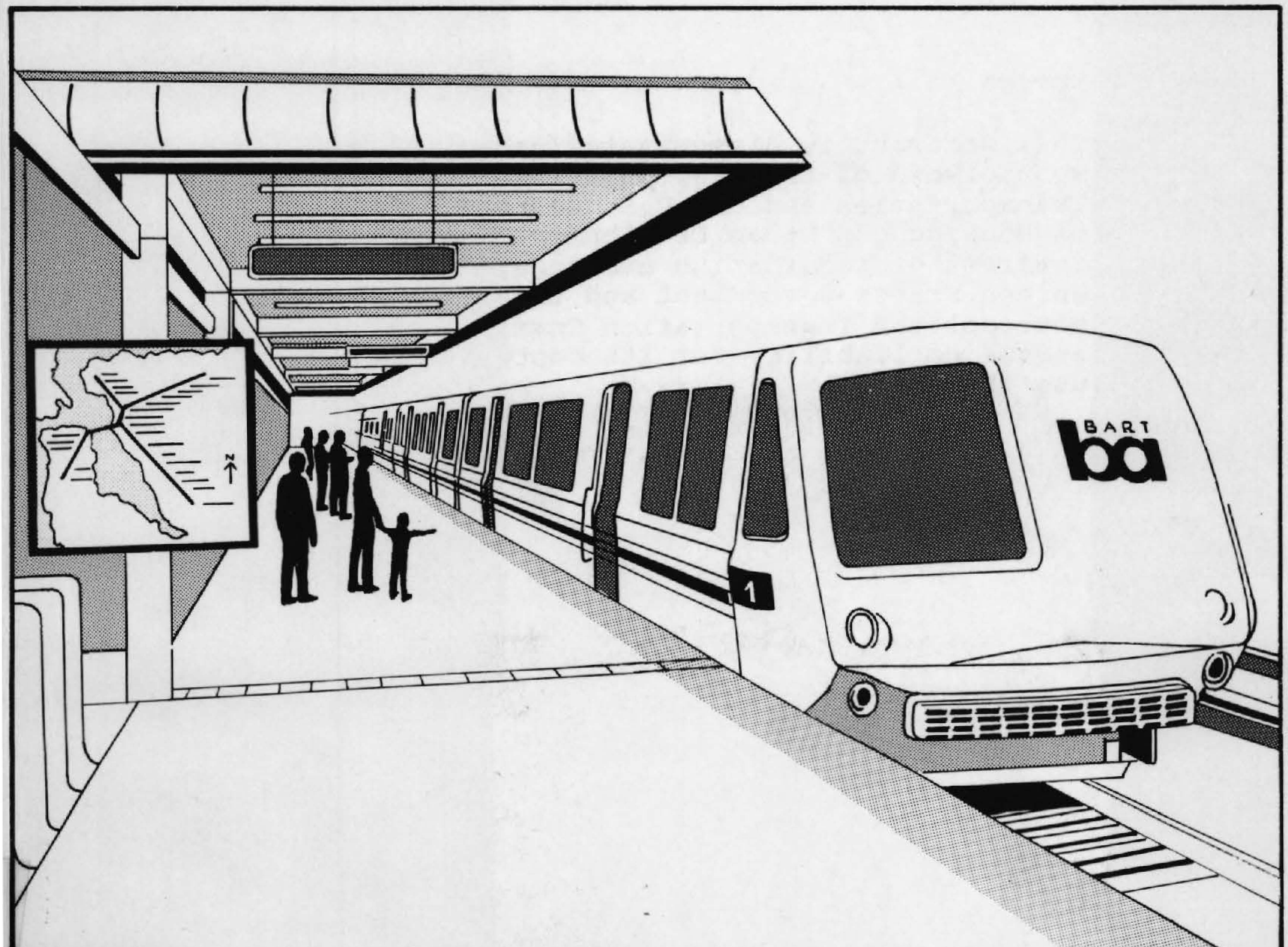
BART Impact Program

BART'S FIRST FIVE YEARS: TRANSPORTATION AND TRAVEL IMPACTS



FINAL REPORT

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The Metropolitan Transportation Commission is the prime contractor for the BART Impact Program. Peat, Marwick, Mitchell & Co. is the subcontractor responsible for the Transportation System and Travel Behavior Project.

16. Abstract

BART, the 71-mile San Francisco Bay Area Rapid Transit System, began passenger service in 1972. The final section, the transbay link between San Francisco and Oakland, opened in 1974. Ridership has grown to about 140,000 passenger trips per day, 60,000 of them transbay. This is the final report of a research study assessing the impacts of BART on transportation and travel in the Bay Area. The BART System, its costs, the service it provides relative to bus and automobile, and the nature of its ridership are described. BART's impacts on modal split, bus ridership and service, and highway traffic and congestion are analyzed; and implications for planning rail transit elsewhere are drawn.

BART's ridership and impacts are less than were widely predicted. This reflects both on the optimism of the predictions and the shortcomings of BART's current service. As intended, BART's most significant improvements in travel times have been for long-distance trips by transit, particularly transbay, to downtown San Francisco. Accordingly, the predominant use of BART is for long-distance commute trips. BART carries 21% of transbay commute trips. Areawide, BART's share of trips for all purposes is between 2% and 3%. Total bus ridership has changed little because the loss of riders from services paralleling BART has been offset by the use of bus to get to and from BART. Impacts on San Francisco-Oakland Bay Bridge traffic have been less than expected because new trips by car have appeared to replace those removed by BART.

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BART IMPACT PROGRAM

BART'S FIRST FIVE YEARS: TRANSPORTATION AND TRAVEL IMPACTS

FINAL REPORT

REPORT NO. DOT-BIP-FR 11-3-78

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

AND

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

WASHINGTON, D.C.

The preparation of this report has been financed in part through a grant from the U.S. Department of Transportation, Urban Mass Transportation Administration, under The Urban Mass Transportation Act of 1964, as amended.

SPONSOR'S NOTE

The BART Impact Program was a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART). The program began in 1972, and was completed in 1978. Financing for the Program was provided by the U.S. Department of Transportation, the U.S. Department of Housing and Urban Development, and the California Department of Transportation. Management of the Federally-funded portion of the Program was vested in the U.S. Department of Transportation (DOT). The Metropolitan Transportation Commission (MTC), a nine-county regional agency established by California law in 1970, administered the Program as prime contractor to DOT; the research was performed by competitively selected subcontractors to MTC.

The BART Impact Program studied the broadest feasible range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors was measured and analyzed.

The results of the BART Impact Program have been synthesized in BART in the Bay Area, the BART Impact Program Final Report (PFR). That report was prepared by MTC and presents MTC's conclusions from and interpretation of the Program's findings. In addition to the PFR, final reports for each of the individual projects in the Program were prepared by the consultants who conducted the research. The reports are listed at the end of this Note. The final reports are supported by numerous technical memoranda and working papers. The conclusions in those documents reflect the viewpoints of the respective consultants based on their research.

Readers of BART Impact Program reports should be aware of the circumstances and the setting in which BART was planned and built and the conditions under which the Program was conducted. An understanding of these factors is critical for interpreting the Program's findings and attempting to apply them to other areas.

First, it is important to note that the San Francisco Bay Area has a sound economy, a good system of highways and public transportation, and distinctive land use and development patterns shaped by the Bay and the hills around it. BART was approved and built during a period of vigorous growth in the Bay Area. The economy was expanding, suburban development was burgeoning, and major increments of highway capacity were being added. Also, the Bay Area already had extensive public transportation services. There were public carriers operating dense networks of local transit services on both sides of the Bay, and there was frequent transbay bus service from many parts of the East Bay to San Francisco. In 1972 before BART opened, approximately 10% of the total daily trips in the three BART counties were made on transit. All of these factors made it difficult in the study to isolate BART's effects from other influences that were affecting such things as travel behavior and urban development.

A second important point is that BART was planned and designed primarily to facilitate travel from outlying suburbs to downtown areas. Multiple stops are provided in the major central business districts, but in other respects BART is more like a commuter rail system (with long lines and widely-spaced stations) than a New York or Chicago-style subway system of interlocking crosstown lines and frequent stops. The BART system was intended to rival the automobile in comfort, speed, and convenience. Contemporary issues like energy conservation, air quality and service for the transportation disadvantaged were not widely recognized and publicized concerns during the period of BART's design.

The institutional setting in the Bay Area was a third important influence on BART's development. BART was developed as a separate institution without full coordination among existing transportation and regional development planning agencies. BART's planners had to make assumptions about policies and development, many of which turned out to be contrary to policies ultimately adopted by municipalities in the BART District.

A critical element in the study design of the BART Impact Program was the definition of the No-BART Alternative (NBA), the regional transportation facilities and travel patterns judged most likely to have evolved by 1976 if BART had not been built. The definition of an NBA was essential since the Program defined an impact as the difference between what actually occurred with BART and what would have resulted without BART. One cannot be certain about what the region would have been like had BART not been built. But based on an analysis of the political and economic decision history of the Bay Area and the professional judgment of those involved in the Program, it was determined that no significant changes to the area's freeway and bridge systems as they actually were in 1976 would have occurred without BART. It was concluded further that the public transit network and services would have been very similar to what they were just before the start of BART transbay service. One consequence of this assumption is that the NBA provides lower levels of service and less capacity than the with-BART system, and attracts fewer riders. The NBA does not extrapolate beyond 1976 and does not consider how much additional capacity in the transportation system might eventually have been required because of increasing travel demand and congestion.

An important factor affecting the findings was that BART was not operating at its full service level during the period of study by the BART Impact Program. The frequency of trains, their operating speeds, the reliability of their operations, and the capacities provided in peak periods of travel by BART were considerably lower than those originally planned. Trains were running on 12-minute headways instead of the 4.5 minutes originally planned for each of the four lines (90 seconds where three lines converged). BART did not initiate service on all lines simultaneously in 1972 but instead phased in service. The most critical link, the Transbay Tube, was not opened until late 1974. Night service did not start until the end of 1975, and Saturday service started in 1977. Direct Richmond to Daly City service still is not operating, and it now appears that "full service levels," when they are attained, will not achieve the headways and average speeds announced in the original plans.

The final point is that BART had only been operating for a relatively short period of time when its impacts were studied. The impact assessment largely depends on data collected in the first four years of BART's operations. It is likely that some of its impacts, particularly those relating to urban development, will require more time to mature.

Final Reports

These documents are available to the public through the National Technical Information Service, Springfield, VA 22151:

Metropolitan Transportation Commission, "BART in the Bay Area. The Final Report of the BART Impact Program," MTC, 1979.

Gruen Associates, Inc. and DeLeuw, Cather & Company, "Environmental Impacts of BART," MTC, 1979.

Peat, Marwick, Mitchell & Co., "BART's First Five Years: Transportation and Travel Impacts," MTC, 1979.

Jefferson Associates, Inc., "Impacts of BART on Bay Area Institutions and Life Styles," MTC, 1979.

McDonald & Grefe, Inc., "The Economic and Financial Impacts of BART," MTC, 1979.

John Blayney Associates/David M. Dornbusch & Co., Inc., "Land Use and Urban Development Impacts of BART," MTC, 1979.

Booz, Allen & Hamilton Inc., "The Impact of BART on Public Policy," MTC, 1979.

Urban Dynamics Associates, "Implications of BART's Impacts for the Transportation Disadvantaged," MTC, 1978.

Alan M. Voorhees & Associates, Inc., "Federal Policy Implications of BART," DOT, 1979.

PREFACE

This is the final report of a 4-year research study to assess the impacts of the San Francisco Bay Area Rapid Transit (BART) System on the transportation system and travel patterns in the Bay Area. The study was conducted by Peat, Marwick, Mitchell & Co., San Francisco, for the Metropolitan Transportation Commission, Berkeley, as part of the BART Impact Program, which is being performed under the sponsorship of the U.S. Department of Transportation and the U.S. Department of Housing and Urban Development.

At different stages of the study, the Peat, Marwick, Mitchell & Co. study team was assisted by staff members of JHK & Associates, San Francisco; Market Facts, Inc., Chicago; and Jefferson Associates, Inc., San Francisco.

Many individuals and organizations provided information and assistance to the study team. Among those who were helpful in providing data on Bay Area transportation and travel are staff members of the following organizations:

- Alameda-Contra Costa Transit District
- Bay Area Rapid Transit District
- California Department of Transportation
- Golden Gate Bridge Highway and Transportation District
- Greyhound Lines
- Public Utilities Commission, State of California
- San Francisco Municipal Railway
- San Mateo County Transit District

Many helpful comments were received from the following individuals who reviewed an earlier draft of the report:

- Mr. Mark Akins, Washington (D.C.) Metropolitan Area Transit Authority
- Mr. Ward Belding, Mr. Keith Bernard, Mr. James Brennan, Mr. Howard Goode, Ms. Miriam Hawley, and Mr. Thaddeus Usowicz, Bay Area Rapid Transit District
- Mr. Steven Colman and Mr. Wolf Homburger, University of California, Berkeley
- Mr. Robert Dunphy, Metropolitan Washington (D.C.) Council of Governments
- Mr. Alfred Harf and Mr. James McQueen, Urban Mass Transportation Administration, U.S. Department of Transportation
- Mr. John Jamieson, Metropolitan Transit Commission, St. Paul, Minnesota
- Mr. Frank Koppelman, Northwestern University
- Mr. Eric Mohr, Transportation Consultant, Kentfield, California
- Mr. Donald Morin and Mr. James Ryan, Federal Highway Administration, U.S. Department of Transportation
- Mr. Manuel Padron, Metropolitan Atlanta Rapid Transit Authority
- Mr. Norman Paulhus and Mr. Edward Weiner, Office of the Secretary, U.S. Department of Transportation

Helpful guidance to the study team was provided at intervals throughout the study by the National Research Council, BART Impact Program Advisory Committee, under the chairmanship of Mr. Milton Pikarsky, and a federal technical advisory committee whose members included, among others, the U.S. Department of Transportation staff members in the preceding list and Mr. George Grainger of the Office of the Secretary of Transportation.

Assistance was provided at all stages of the study by members of the BART Impact Program staff of the Metropolitan Transportation Commission, Berkeley, including Mr. Henry Bain, Mr. William Davidson, Mr. Joel Markowitz, Ms. Marilyn Reynolds, Mr. Gordon Shunk, and Mr. Andrew Ungar. Mr. Markowitz, who was the assistant project manager for the study, provided especially valuable guidance and assistance throughout. Also, Ms. Miriam Hawley of the Bay Area Rapid Transit District, who acted as liaison between the District and the BART Impact Program, was most helpful in providing assistance and information about BART operations.

The many contributions of all of these and other individuals and organizations are gratefully acknowledged. However, responsibility for the contents of the report and any errors therein rests with Peat, Marwick, Mitchell & Co. Among Peat, Marwick, Mitchell & Co. staff members who contributed to the study are Richard Worrall, who was the responsible principal throughout the study; Raymond Ellis, who was manager for the first phase; and Alistair Sherret, who was manager for the second phase. Other Peat, Marwick, Mitchell & Co. professional staff members who made substantial contributions to the analyses summarized in this report are Gary Barrett, Stephen Cohn, Nicholas Davidson, Steven Etkin, and Henry Fan.

BART'S FIRST FIVE YEARS: TRANSPORTATION AND TRAVEL IMPACTS

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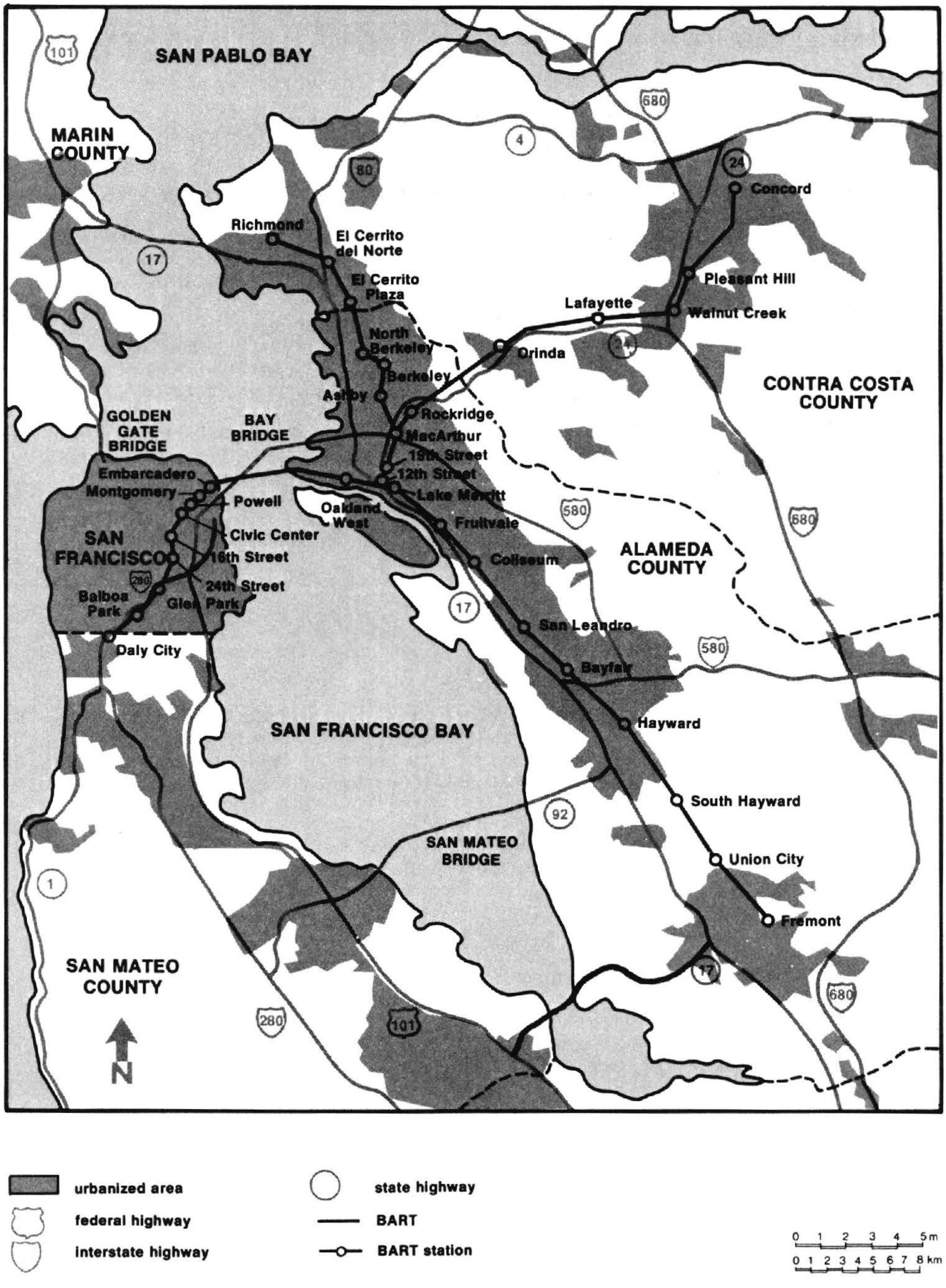
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Ashby
Rockridge
MacArthur
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Lake Merritt
Fruitvale
Coliseum
San Leandro
Bayfair
Hayward
South Hayward
Union City
Fremont
Concord
Pleasant Hill
Walnut Creek
Lafayette
Orinda
CONTRA COSTA COUNTY
ALAMEDA COUNTY
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GOLDEN GATE BRIDGE
BAY BRIDGE
Embarcadero
Montgomery
Powell
Oakland West
Civic Center
SAN FRANCISCO
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Balboa Park
Glen Park
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BART
BART station
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BART: The Bay Area Rapid Transit System

Length: The 71-mile system includes 20 miles of subway, 24 miles on elevated structures and 27 miles at ground level. The subway sections are in San Francisco, Berkeley, downtown Oakland, the Berkeley Hills Tunnel and the Transbay Tube.

Stations: The 34 stations include 13 elevated, 14 subway and 7 at ground level. They are spaced at an average distance of 2.1 miles: stations in the downtowns are less than one-half mile apart, while those in suburban areas are two to four miles apart. Parking lots at 23 stations have a total of 20,200 spaces. There is a fee (25 cents) at only one of the parking lots. BART and local agencies provide bus service to all stations.

Trains: Trains are from 3 to 10 cars long. Each car is 70 feet long and has 72 seats. Top speed in normal operations is 70 mph with an average speed of 38 mph including station stops. All trains stop at all stations on the route.

Automation: Trains are automatically controlled by the central computer at BART headquarters. A train operator on board each train can override automatic controls in an emergency.

Magnetically encoded tickets with values up to $20 are issued by vending machines. Automated fare gates at each station compute the appropriate fare and deduct it from the ticket value.

Fares: Fares range from 25 cents to $1.45, depending upon trip length. Discount fares are available to the physically handicapped, children 12 and under, and persons 65 and over.

Service: BART serves the counties of Alameda, Contra Costa and San Francisco, which have a combined population of 2.4 million. The system was opened in five stages, from September 1972 to September 1974. The last section to open was the Transbay Tube linking Oakland and the East Bay with San Francisco and the West Bay.

Routes are identified by the terminal stations: Daly City in the West Bay, Richmond, Concord and Fremont in the East Bay. Trains operate from 6:00 a.m. to midnight on weekdays, every 12 minutes during the daytime on three routes: Concord-Daly City, Fremont-Daly City, Richmond-Fremont. This results in 6-minute train frequencies in San Francisco, downtown Oakland and the Fremont line where routes converge. In the evening, trains are dispatched every 20 minutes on only the Richmond-Fremont and Concord-Daly City routes. Service is provided on Saturdays from 9 a.m. to midnight at 15-minute intervals. Future service will include a Richmond-Daly City route and Sunday service.* Trains will operate every six minutes on all routes during the peak periods of travel.

Patronage: Approximately 146,000 one-way trips are made each day. Approximately 200,000 daily one-way trips are anticipated under full service conditions.

Cost: BART construction and equipment cost $1.6 billion, financed primarily from local funds: $942 million from bonds being repaid by the property and sales taxes in three counties, $176 million from toll revenues of transbay bridges, $315 million from federal grants and $186 million from interest earnings and other sources.

March 1978

***Sunday service began in July, 1978**

BART Impact Program

Transportation System and Travel Behavior Project

BART'S FIRST FIVE YEARS: TRANSPORTATION AND TRAVEL IMPACTS

SUMMARY AND CONCLUSIONS

Peat, Marwick, Mitchell & Co.
San Francisco, California

May 1978

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BART's First Five Years: Transportation and Travel Impacts

SUMMARY AND CONCLUSIONS

INTRODUCTION

BART, the 71-mile long San Francisco Bay Area Rapid Transit System, is the first new regional-scale rail rapid transit system built in the United States in over 50 years. BART has been in operation for over 5 years and has provided service on all lines of the System for over 3 years. Service levels have not yet reached those ultimately planned, and ridership continues to grow, so the ultimate level of BART's impacts cannot yet be established. Nevertheless, BART's current ridership level of about 140,000 trips per day allows the nature of its impacts to be assessed with some confidence. Even though BART's impacts are continuing to emerge, now is an appropriate time to attempt to draw conclusions from the BART experience.

Study Scope and Objectives

This report presents an assessment of BART's impacts on the transportation system and travel patterns in the San Francisco Bay Area. It is the final report of a 4-year study and summarizes findings and conclusions detailed in several earlier reports. The study is one of several conducted as part of the BART Impact Program, a federally funded research program covering the entire range of potential impacts of rapid transit. Other BART Impact Program studies have assessed BART's effects on land use and urban development, the environment, the regional economy, social institutions and life-styles, and public policy. Findings and conclusions from all the BART Impact Program studies will be integrated in the Program's final report, scheduled for publication later in 1978.

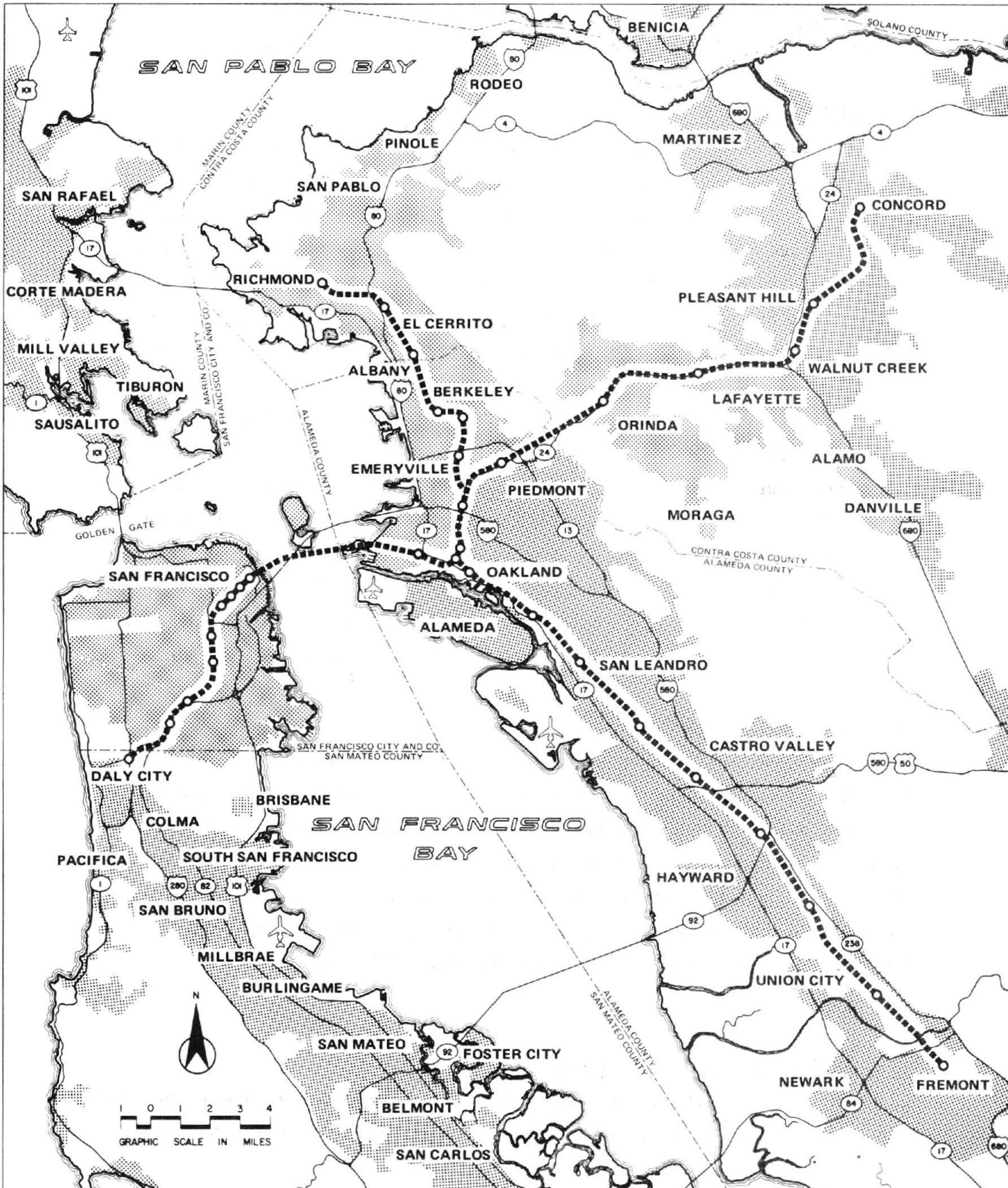
The objectives of the present report are (1) to describe the BART System, the service it provides, the characteristics of the area it serves, and its cost; (2) to describe the determinants and nature of ridership on the System; and (3) to assess BART's impacts on the modal split of travel between public transit and private car, on bus ridership and bus service levels, and on highway traffic and congestion. The intent of the report is not to provide a costs-versus-benefits evaluation of BART, nor to argue for or against the building of rail rapid transit in other areas. Rather, the intent is to provide an independent assessment of BART and its impacts on travel patterns which will be valuable to transportation planners and designers, the public, and others who must make future decisions about rapid transit in the Bay Area and other urban areas.

Basis for Impact Assessment

Assessment of BART's impacts depends, whether explicitly or implicitly, on a comparison of "with-BART" and "without-BART" transportation systems and travel patterns. The with-BART transportation system and the associated travel patterns can be observed directly and for the most part are reasonably clearly defined. However, the hypothetical without-BART alternative against which BART impacts are measured is not uniquely defined and must be assumed in the analysis. Conclusions about BART's impacts depend very heavily on the characteristics of the without-BART alternative and the associated travel patterns assumed.

In this report, BART's impacts are judged relative to an assumed without-BART alternative in which bus and highway transportation services are provided at levels close to those existing immediately before the start of BART service in 1972. This hypothetical transportation network has been judged (by BART Impact Program analyses of the Bay Area's recent political and economic history) to represent the transportation system most likely to have evolved by 1976 had BART not been built. Thus, BART's impacts are assessed relative to what is, in effect, a "do-nothing" alternative. The assumed hypothetical without-BART alternative would not provide as extensive transit service as is currently provided by the with-BART system; it would not be capable of carrying current transit ridership; nor would it have required anything approaching the capital investment made in BART.

It is important to bear this definition of the without-BART alternative in mind when interpreting the findings and conclusions given in the report. Different hypothetical without-BART alternatives--involving higher investment in improved bus services or highways, for example--would likely lead to rather different conclusions about BART's impacts, but these alternatives have not been analyzed in this study.



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

SAN FRANCISCO BAY AREA RAPID TRANSIT

THE BART SYSTEM AND SERVICE PROVIDED

The BART System and Service Area

BART serves the central cities of San Francisco and Oakland, and other Bay Area cities and suburbs. The System was opened in stages from September 1972 to September 1974, the last stage being the line beneath San Francisco Bay linking downtown San Francisco to Oakland and other cities and communities in the East Bay. BART's four routes radiate from central Oakland and are identified by the terminal stations: Daly City in the West Bay, and Richmond, Concord, and Fremont in the East Bay.

BART serves areas of Alameda, Contra Costa, and San Francisco counties (the three tax-paying BART District counties) and parts of northern San Mateo County. The "greater" BART service area, defined by the three BART District counties and northern San Mateo County, had a 1975 population of 2.6 million and an urbanized area of 330 square miles. Of course, some parts of this area are served more effectively than others. The more immediate "primary" BART service area, which accounts for 80% of BART trip origins, had a 1975 population of 1.6 million.

Distances between the 34 BART stations average 2.1 miles and range from less than 0.5 mile in downtown San Francicsco to over 3 miles in the farthest suburbs on the Concord and Fremont Lines. Approximately 20 miles of the System are located underground, 24 miles are on elevated structures, and 27 miles are at grade or on earth embankments. Included in the underground portion is the 4-mile long Transbay Tube constructed in a submerged trench beneath San Francisco Bay, and a 3-mile long rock tunnel through the Berkeley Hills on the Concord Line.

BART Capital and Operating Costs

BART cost $1,636 million to build and put into operation, about $642 million more than originally estimated. Virtually all of this 65% increase is attributable to changes in scope from the originally planned system, higher-than-expected inflation, and, above all, inflation costs associated with delays to the planned construction schedule.

For the fiscal year ending June 1977, BART's operating expenses (net of capitalized costs) totaled $67 million, of which $25 million or 37% was covered by passenger fare revenues. Almost half of BART's operating expenses were for maintenance. This is a much higher proportion than is typical for other rail transit systems and reflects BART's continuing efforts to overcome persistent unreliability problems. BART's fiscal year 1977 operating costs of $1.93 per passenger-trip were higher than is typical for other U.S. rail transit systems. However, taking into account the relatively long (13-mile) average length of BART trips, the average BART cost of $0.15 per passenger-mile is not much different from the per-passenger-mile cost of other systems.

BART Planning Objectives

BART was conceived as a high-quality regional rapid transit system that would offer travel times and service levels competitive with the automobile, especially for peak-period travel from the more remote suburbs to the central business districts of San Francisco and Oakland. By attracting automobile commuters from their cars, BART was intended to relieve what a 1962 planning report projected to be "the continuing increase of traffic congestion which threatens the future growth and well-being of the San Francisco Bay Area." The System was not designed particularly to serve short-distance trips within the central cities or off-peak travel.

The objective that BART provide fast, comfortable, and convenient no-transfer service that would be attractive to long-distance automobile commuters translated into a set of stringent design specifications for the System. These specifications called for high-speed (80 miles per hour) trains operating at short (90-second) headways and providing sufficient passenger capacity to enable all passengers to be seated. The specifications also dictated a fully automatic train control system, which was regarded as essential for safe operation at the planned headways and operating speeds, especially for trains merging from the three East Bay lines into the single transbay link.

Not all BART's design objectives have been fully met. Moreover, the attempt to achieve them through the use of complex and sometimes innovative and unproven technology underlies many of the technical problems with the BART cars and automatic train control system which adversely affect the level and reliability of service offered.

BART Service Levels

On weekdays, BART trains are scheduled to run every 12 minutes during the daytime on three routes: Concord-Daly City, Fremont-Daly City, and Richmond-Fremont. This results in 6-minute scheduled train frequencies in San Francisco, downtown Oakland, and on the Fremont Line where two routes converge. Richmond-Daly City passengers are currently required to transfer between trains. In the evenings, trains are scheduled to run every 20 minutes on just two routes, Richmond-Fremont and Concord-Daly City. The pattern of Saturday service is similar to weekday service, with trains running slightly less frequently during the daytime but slightly more frequently in the evening. Trains do not currently run on Sundays, although Sunday service, along with direct Richmond-Daly City service, is on the list of improvements intended for introduction in 1978.

Under normal conditions, the maximum scheduled train speed between stations is 70 miles per hour on the suburban sections of the System but less in the central areas where stations are closer together. Including time spent by trains at stations, the average station-to-station scheduled travel speed for a trip on BART is about 36 miles per hour.

Trains vary in length by line and time of day; the maximum train length is 10 cars (720-seat capacity) at peak periods. When trains are running on schedule, seats are generally available on trains at all times except for fairly short peak periods, and overcrowding is not currently an important deterrent to ridership. BART cars are attractive, quiet, and comfortable and have air-conditioning, upholstered seats, carpeting, and large tinted windows.

The BART stations also reflect the desire of the System's designers to provide a pleasant environment for the traveling public; the stations are constructed to very high standards in a variety of architectural styles. All stations have elevators for use by people whose physical disabilities make their use of the stairs or escalators difficult.

Fares vary, according to distance, from a minimum of $0.25 for short trips within central San Francisco and Oakland to a maximum of $1.45 for the longest trip on the System. The average fare paid for all trips on the System (for an average on-BART trip distance of about 13 miles) is $0.75. Fares are generally slightly higher than those for comparable bus journeys. BART is equipped with an automated fare collection system based on the concept of "stored fare." Passengers buy magnetically encoded tickets in amounts ranging from $0.25 to $20.00 and use the same ticket for journeys on the System until its value is used up.

Because of unexpectedly high failure rates in many components of the System and problems encountered in repair and maintenance, BART has had difficulty, until recently, in making sufficient cars available to provide desired service levels. Equipment problems have also caused frequent in-service train failures (often requiring the off-loading of passengers and removal of trains from service), and have necessitated reduced train speeds in rainy weather. Although BART has devoted considerable resources to remedying these problems, and has been successful in improving car availability and other measures of reliability, the

System continues to be plagued with delays. These delays have given rise to a widespread perception of BART as undependable, with consequent impacts on people's willingness to ride the System.

Parking at BART Stations

Parking space is provided at 23 of the 34 BART stations; most of these stations are in the suburban areas of the East Bay. The lots vary in capacity from 200 to 1,600 spaces and provide a total of 20,300 spaces. This total is considerably lower than the 36,000 spaces originally planned, and 2,200 spaces have been added over the last 3 years in response to shortages at several stations. However, the added spaces have not removed capacity constraints; parking lots are typically filled as early as 7:30 a.m. at some stations. Parking is free at all but one station, and some spaces are reserved for midday parkers. Provision is also made for people being dropped off or picked up by car, but such "kiss-and-ride" facilities are not a major feature of BART station design.

Other Bay Area Transit Services

The area served by BART is comprehensively served by two major bus operators, the San Francisco Municipal Railway (MUNI) in the City of San Francisco (which also operates streetcars, cable cars, and electric trolley buses), and the Alameda-Contra Costa Transit District (AC Transit) in the East Bay. These two (and several smaller transit operators) are organizationally and financially separate from BART and from one another.

Bus service is provided to all 34 BART stations, at varying service levels. Most of this service is provided by local bus lines which have been modified to varying degrees to connect with BART. In addition, under contract to the BART District, AC Transit operates several new bus lines between BART stations and outlying suburban areas of Alameda and Contra Costa counties. The principal operators of service to BART stations also operate local and express bus lines, which, to varying degrees, parallel BART routes. BART passengers using MUNI or AC Transit bus to get to and from a BART station pay only half the normal round-trip bus fare.

Getting To and From BART

Modes of getting to and from BART stations vary greatly depending on station location. In the suburban areas of the East Bay, the automobile is used predominantly. In the more densely developed residential areas of San Francisco and the East Bay cities, bus and walking are more important access modes. Overall, at the (home) origin end of the trip, 40% of BART travelers drive to and park at the station, 17% are dropped off by car, 20% get to the station by bus, and nearly all the remaining 23% walk. At the (non-home) destination end of the trip, 78% of BART travelers walk from the station; and, reflecting BART's design goal of bringing people close to their downtown destinations, the percentage is higher still for the central San Francisco and Oakland stations. The time spent getting to and from the stations varies with the mode used but is typically about 10 minutes at each end of the trip. Thus, in the average BART journey to work, about 20 minutes of the 50-minute door-to-door total is spent getting to and from the station.

DETERMINANTS AND NATURE OF BART RIDERSHIP

Travel Times by BART

As originally intended, BART's most significant effects on travel times have been to reduce the times required to travel by public transit from the more distant East Bay suburbs to downtown San Francisco and Oakland. The System has provided relatively small travel time improvements, if any, for short-distance and non-downtown travel, particularly in inner suburban and central city areas already well served by bus. Transit travel times have been improved more for travel from the Concord and Fremont Lines than from the Richmond Line, reflecting the current need to change trains for BART journeys between Richmond and San Francisco, but this is likely to change soon, when direct Richmond-Daly City service begins in 1978.

A comparison of travel times between traffic zones throughout the greater BART service area (as estimated from network representations of the transportation system) shows that BART has reduced average peak-period transit travel times to major employment centers from 46 minutes to 40 minutes, or 12%, relative to the without-BART transit alternative. BART has improved travel times by public transit more in the off-peak than in the peak periods, reflecting the relatively high frequency of BART service throughout the day.

Although BART provides significant potential travel time improvements when compared with the without-BART transit alternative, most door-to-door journeys by BART still take much longer than those possible by car on the current highway system, even at periods of peak highway congestion (again, comparing zone-to-zone average travel times estimated from networks). This is true for virtually all zone-to-zone trip movements, including those in the corridors best served by BART and the long-distance trips the System was originally designed to serve. Thus, with few exceptions, BART has not provided travel times competitive with the automobile as intended.

For travel from all parts of the greater BART service area to major employment centers, the estimated average door-to-door travel time of 40 minutes for the with-BART network compares with an average of 26 minutes by car in the peak period (a 52% difference). The advantage by car is greater still at off-peak times. Time people must spend getting to and from the BART station accounts for much of the difference.

<u>Other Factors Influencing BART Ridership</u>

In addition to relative travel times, many service characteristics of the available modes influence travelers' mode choice decisions between BART and bus or automobile. These characteristics are analyzed in the report in terms of travelers' perceived satisfaction with the service offered by the alternative modes, and the importance attached by the travelers to the various service attributes.

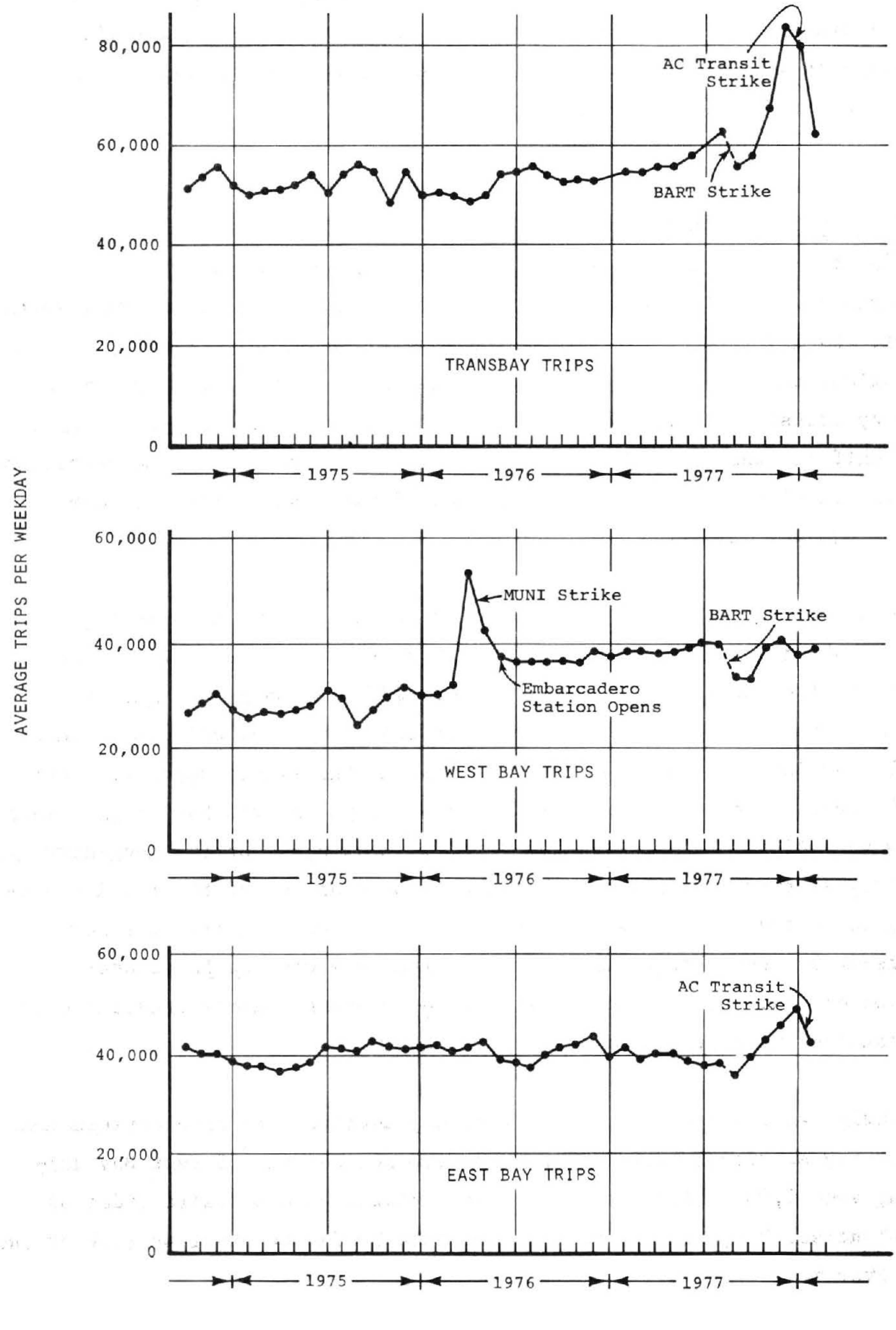
Perceptions of BART service vary among travelers and with the circumstances of their mode choices, but show a fairly consistent overall pattern. Travelers generally perceive BART favorably with regard to its "qualitative" attributes: the comfort of the ride, safety from accident, security from crime, and, among travelers who would otherwise use their automobiles, the opportunity BART provides to devote attention to something other than driving in traffic. Travelers are generally much less satisfied with BART's reliability of service, the time they must spend waiting for trains, total journey times, and, particularly among those who make a choice between BART and bus, the cost of the journey.

The importance travelers attach to the various service attributes in their mode choice decisions also varies among individuals, but typically, the important determinants of choice are the time spent traveling (particularly the time spent waiting for BART or bus), the reliability of service, and the relative travel cost. The qualitative aspects of service, such as comfort, safety, crowding levels, and security, do not appear to be important considerations in most people's current choices between BART and bus or BART and car.

However, the list of factors reported by travelers as being the important determinants of choice varies significantly as a function of the mode choice made. Among people choosing to take the bus to work rather than ride BART, the lower cost of the bus and its more dependable service are reported as important considerations, along with the total travel time required and "inconvenience" of the trip. The term "inconvenience" is used by travelers to mean different things, but to most people the time and trouble involved in having to transfer between transit vehicles (either bus or BART) are important aspects of the inconvenience factor. That avoiding having to transfer is an important factor in travelers' choices is evidenced by the much lower BART ridership on the Richmond-Daly City route, where a transfer between trains is currently required, than on the direct Concord-Daly City and Fremont-Daly City routes.

Among people who choose to drive to work rather than ride BART, the inconvenience of having to get to the BART station and wait for trains, and the unreliability of BART service are typically reported as the important factors, along with total trip travel time. Difficulty in finding parking space at some BART stations contributes to the inconvenience of using BART and is an important determinant in some people's decisions to drive instead. Limited station parking does not appear to be a critical constraint on overall BART ridership currently, but its importance will undoubtedly increase as demand increases.

People's decisions to ride BART rather than the bus to work are largely determined by the travel time savings possible on BART. These savings outweigh the typically higher cost of the BART journey (relative to the bus). People who elect to ride BART to work rather than drive generally accept that it takes longer and is less convenient and reliable than



HISTORICAL BART RIDERSHIP

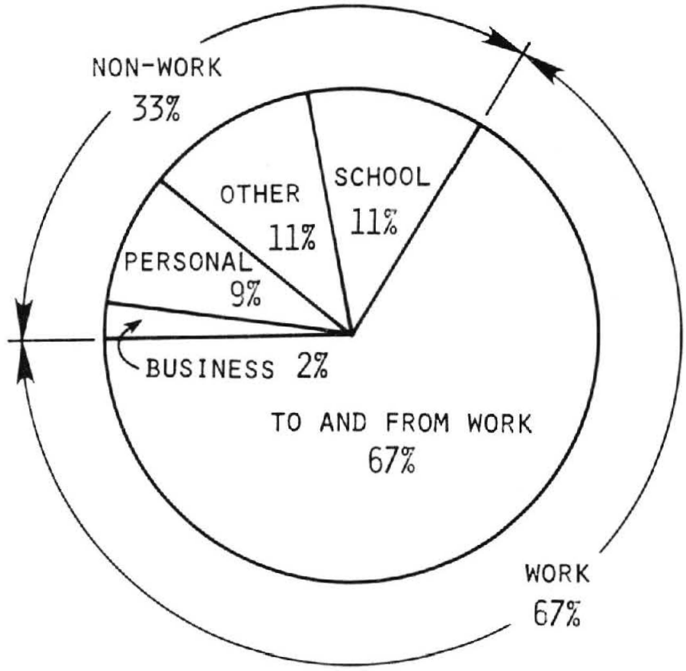
driving, but think that these disadvantages are outweighed by BART's advantages--primarily its lower cost (relative to the car), and the opportunity it provides them to avoid the aggravations of driving in congested traffic and finding parking at their destinations.

BART Ridership Characteristics

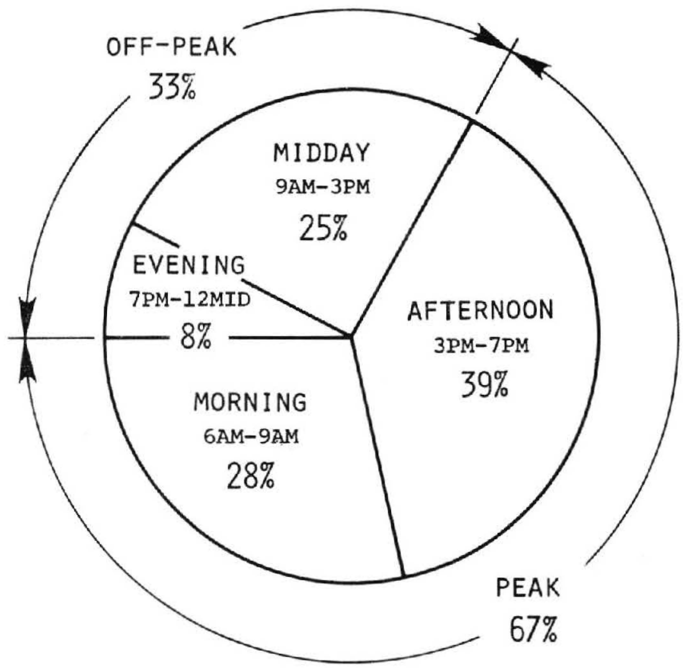
BART's service advantages are such that the System currently carries approximately 140,000 passenger trips per weekday. This total represents between 2% and 3% of all person-trips made by automobile or public transit throughout the greater BART service area, and 18% of all person-trips made by transit throughout the area. Current ridership is just slightly over half the weekday ridership originally projected for System operation at full service levels, and is about 80% of the BART District's most recent projections for 1981.

In total, weekday BART ridership appears to have grown at an average rate of about 5% per year over the 1-1/2 years since the last station of the System, Embarcadero, opened in May 1976. (The growth rate is difficult to estimate confidently, given the disrupting effects of recent strikes at BART and AC Transit). As shown in the figure opposite, most of the recent increase in ridership has occurred in transbay trips. This increase reflects BART's relative service advantages for the long-distance transbay journeys which must otherwise be made on one of the two increasingly congested toll bridges across the Bay. Average daily West Bay ridership has not changed much over the months since the Embarcadero Station opened, and East Bay ridership has remained fairly constant over the entire 3-year period shown in the figure.

Currently, 40,000 passenger trips (weekday average) are made between the 9 West Bay stations; 40,000 trips are made between the 25 East Bay stations; and 60,000 trips are made between stations on opposite sides of San Francisco Bay, making the Transbay Tube by far the busiest link of the BART System.



BART TRIP PURPOSE DISTRIBUTION

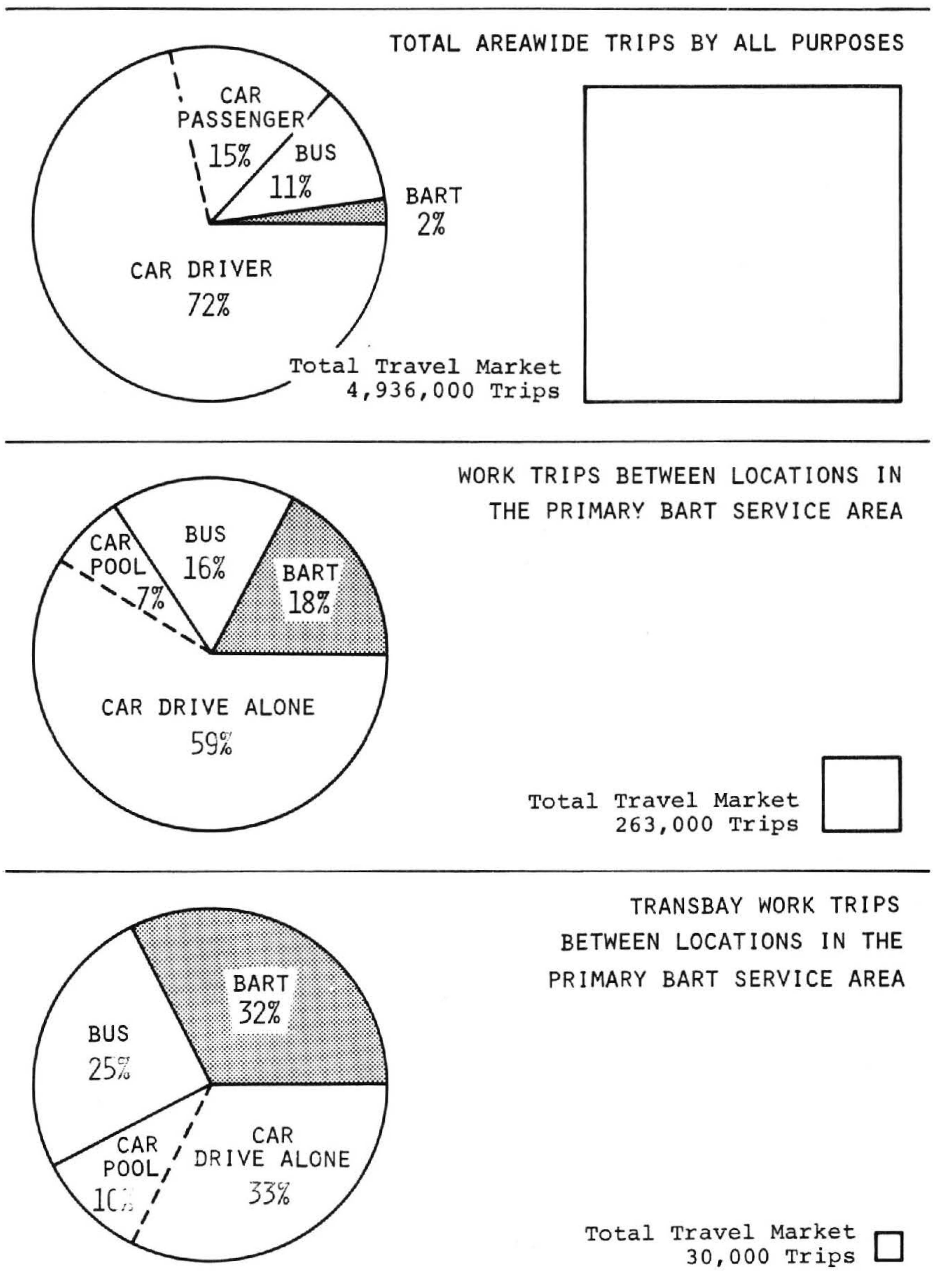


BART TRIP TIME-OF-DAY DISTRIBUTION

The predominant use of BART is for long-distance commute trips, particularly to workplaces in downtown San Francisco. As shown in the figure opposite, about 67% of all BART passenger trips made on weekdays are to and from work, and consistent with this pattern, ridership tends to be heavily concentrated in the morning and evening peak periods. During the 2 hours from 7:00 a.m. to 9:00 a.m., close to 40,000 passengers typically exit the System. Of these, 60% exit at one of the four downtown San Francisco stations, and another 17% exit from one of the three downtown Oakland stations. Most of the work trips to downtown San Francisco are from the three outlying Daly City Line stations and from stations on the Concord Line. Because of the predominant use of BART for commuting, travel volumes on most BART line segments are heavily "tidal" in character. For example, in the morning peak, 90% of transbay trips are toward San Francisco and only 10% are in the reverse direction.

The average journey to work by BART covers about 17 miles (13 miles on BART itself, and 4 miles to and from stations), and takes about 50 minutes (including time spent getting to and from the stations and waiting for the train). Work trips made by automobile from residences in the greater BART service area are much shorter, averaging 9 miles (and 20 minutes' travel time).

The socioeconomic profile of BART riders is broadly representative of the service area population, but it also reflects the heavy use of the System by people getting to and from white-collar employment in the downtown areas. The typical BART user is between 25 and 35 years old, and relatively well educated. Men and women are about equally represented. The use of BART by people of different ethnic groups and income levels is roughly in proportion to their share of the service area population.



BART'S SHARE OF TRAVEL

Note: Areas of Squares Indicate Travel Market Sizes

BART IMPACTS

Impacts on Modal Split

Approximately 5 million person-trips are made each weekday by public transit or private car by people living in the greater BART service area. An estimated 2 or 3% of these trips are made by BART, 10 or 11% by bus, and 87% by automobile. Thus, BART's share of all areawide travel is relatively small, and the impacts that stem from its share of areawide travel volumes--such as its contribution to reducing areawide vehicle-miles of automobile travel, traffic congestion, fuel consumption, and air pollution--are correspondingly small.

However, BART's share of particular, more narrowly defined segments of the travel market is considerably higher. For example, if only areawide trips to and from work are considered, BART's share increases to about 5%. Within the primary BART service area, BART's share of work travel is 18%. In the heavily traveled San Francisco-Oakland Bay Bridge corridor, BART accounts for 21% of travel to and from work, and 32% if only transbay work trips made between locations inside the primary BART service area are considered. Of trips to work in the San Francisco central business district from residences in the area served by the BART Concord Line, an estimated 53% are made by BART. In other words, BART's share of travel depends heavily on how the travel market is defined, as illustrated graphically in the figure opposite. Although its share of total areawide travel is small, BART is capturing significant shares of travel in particular smaller markets and corridors, which, for the most part, are those the System was designed to serve.

At the same time, it must be acknowledged that, even in the travel markets it was designed to serve, many trips which could be made by BART are currently being made by bus or automobile. If BART's total work trip market is defined as those trips which survey respondents say they could make by BART, BART currently is the first choice mode for about 40%. The remaining 60% represent a large potential market of BART riders which the System is not capturing, so far anyway.

Analysis of the previous mode of current BART riders suggests that between 5% and 10% of BART trips would probably not be made at all if BART were not available. Of the remainder, about half are trips that, without BART, would probably be made by bus, and half are trips that would be made by automobile. In the East Bay, most of BART's ridership is drawn from automobile. In San Francisco and for transbay travel, BART's ridership is drawn mainly from bus. The higher diversion from bus in San Francisco and transbay reflects the generally higher levels of pre-BART bus service provided in these corridors than existed in the East Bay.

As mentioned, BART's share of total areawide trips is small. When this small share is combined with the relatively high percentage of BART trips which, without BART, would probably be made by bus, an even smaller impact on areawide modal split is revealed, even among work trips. A comparison of U.S. Census journey-to-work data in the three BART District counties for 1970 and 1975 suggests a 2% overall change in the work trip modal split between automobile and transit (from 80% automobile, 20% transit pre-BART to 78% automobile, 22% transit post-BART); and some part of this change may be attributable to factors other than BART. But again, BART's impacts are more obvious in particular travel corridors. In the San Francisco-Oakland Bay Bridge corridor, the split between automobile and transit modes (for travel for all purposes) changed from 76% automobile, 24% transit before the start of transbay BART service to 68% automobile, 32% transit afterwards.

Impacts on Bus Ridership

BART is now used for about 18% of all transit trips made in the greater BART service area, and, as noted, many current BART riders previously used the bus for the line-haul portion of their trips. Nevertheless, the impacts on bus ridership on the AC Transit and MUNI systems are small and extremely difficult to detect from aggregate bus ridership data, given other sources of variation. The reason for this small overall change in bus ridership is that the loss of bus riders from line-haul services paralleling BART has been offset by people who ride the bus to get to and from BART.

In San Francisco, an estimated 23,000 daily passenger trips currently made by BART would be made by MUNI bus if BART were not available. But these line-haul trips have been offset by 17,000 access trips made by people using MUNI to get to and from BART. In the East Bay, an estimated loss of 10,000 daily line-haul trips has been offset by 27,000 access trips made by people using AC Transit East Bay bus services to get to and from BART.

BART's greatest impacts on bus ridership have been in the transbay corridor. In 1976, an average of about 53,000 transbay BART trips were made daily in both directions combined, and over half of these were diverted from AC Transit and Greyhound buses. In this case, the loss of about 28,000 daily passenger trips from line-haul bus services has not been offset by the use of transbay buses as feeders to BART.

The bus access trips gained are generally much shorter than the line-haul trips lost, and they produce a lower fare box revenue per trip, largely because of the 50% discount fare for travelers transferring between MUNI or AC Transit and BART. (However, this fare box revenue loss is made up by an operating subsidy.) Thus, the number of trips lost is not strictly comparable to the number gained; but taking the two together shows a net BART-related loss to the existing bus systems of 17,000 trips daily, or only about 3% of the combined daily ridership on the MUNI, AC Transit, and Greyhound systems.

Impacts on Bus Services

Changes in the MUNI and AC Transit bus systems reflect BART's offsetting influences on the demand for parallel and feeder services. Improved feeder bus service has been provided by rerouting and increasing service on several MUNI lines, but generally, bus services paralleling BART have not been downgraded to the degree some planners proposed. No MUNI line has been discontinued as a result of BART. Similarly, in the East Bay, AC Transit has introduced new bus lines and rerouted or extended existing lines to improve feeder service to BART. But on only a few lines paralleling BART has bus service been reduced, and, to date, on only one has service been discontinued altogether.

In some cases, proposals for service reductions were prevented or delayed by public protest. In other cases, the lower-than-expected cutbacks stem from the slow response of the bus system managers to changes in demand. For the most part, however, the service cutbacks simply reflect the reduced demand. Although BART effectively offers a parallel service to some bus lines, many people continue to use the bus because, all things considered, the bus offers better service for their journeys.

Only on the transbay lines have bus services been obviously reduced because riders have been lost to BART. Greyhound express commuter bus services to San Francisco from the suburbs of central Contra Costa County, which have been largely duplicated by BART Concord Line service, have been reduced most drastically; the more-than-80% reduction in bus vehicle-trips is approximately in proportion to the drop in Greyhound transbay ridership from over 12,000 passenger trips per day to under 2,000 trips per day.

AC Transit transbay services have also been cut back as a result of BART's starting service, but much less severely than Greyhound's. Total scheduled bus miles AC Transit transbay lines were reduced by only 9% in the year after transbay BART service began. On the bus lines experiencing the greatest reduction (those paralleling Fremont-San Francisco BART service), headways have increased only from about 5 minutes to 10 minutes in the peak period. Again, the new levels of transbay bus service largely reflect the demand; even where BART apparently duplicates bus service, many people continue to ride the bus because it offers a more convenient, no-transfer, more reliable, cheaper, and often faster journey. Buses currently carry about 40,000 transbay passenger trips daily in both directions combined, compared with BART's 60,000 trips.

Impacts on Traffic Volumes and Congestion

BART's impact on automobile traffic and highway congestion is extremely difficult to assess, given the many other parallel influences on traffic patterns and the consequent uncertainties associated with estimating highway volumes that would have occurred without BART. But overall, BART's impacts on traffic volumes and congestion in major corridors have been very much smaller than was generally anticipated.

One of the most heavily traveled highway links in the Bay Area is the San Francisco-Oakland Bay Bridge (generally known as the Bay Bridge). The Bay Bridge has five lanes in each direction which typically carry over 95,000 vehicles daily in each direction, about half of these in the peak periods of 6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m. As mentioned earlier, the BART Transbay Tube, paralleling the bridge, is the busiest link of the BART System, often carrying over 30,000 trips per day in each direction, over half of these during the same congested peak periods. The prospect of increasing traffic congestion on the bridge was perhaps the single most important factor in the original decision to build BART, and BART was promoted and widely expected to have major impacts on bridge traffic volumes.

In the Bay Bridge corridor, it appears that the introduction of BART service had the immediate effect of reducing highway traffic flow by roughly 3,000 vehicle-trips per day in each direction. This reduction is significant, statistically speaking, but nevertheless small, both in relation to the total volume of transbay traffic and to the anticipated reduction. The reduction represents about 2 years' historical growth in Bay Bridge traffic and is of the same order as normal week-to-week variations in traffic volumes. Two years after transbay BART began service, traffic volume on the bridge had risen to a level that might reasonably have been anticipated without BART.

Corresponding to the drop in vehicle volumes, average highway travel times across the Bay Bridge were reduced measurably immediately after BART began service, and the period of heaviest congestion was shortened. However, 2 years after BART service began, whatever reductions in congestion BART achieved had evaporated.

Analysis of traffic volumes through the Caldecott Tunnel on Route 24 (the freeway paralleling the BART Concord Line) yields similar findings; BART apparently reduced traffic by about the equivalent of 2 years' established traffic growth, but again, this reduction has been offset by subsequent traffic increases.

BART's impacts on areawide traffic volumes and congestion have not been analyzed explicitly in this study. However, the relatively small impacts found for the major corridors analyzed (which are among the corridors most affected by BART) suggest that BART's impacts on aggregate areawide traffic volumes and congestion have almost certainly been so small as to be undetectable, given variations in the many other factors influencing traffic. Impacts related to overall changes in vehicle-miles of travel, such as reductions in gasoline consumption and automobile exhaust pollution, are correspondingly small.

Impacts on Total Travel

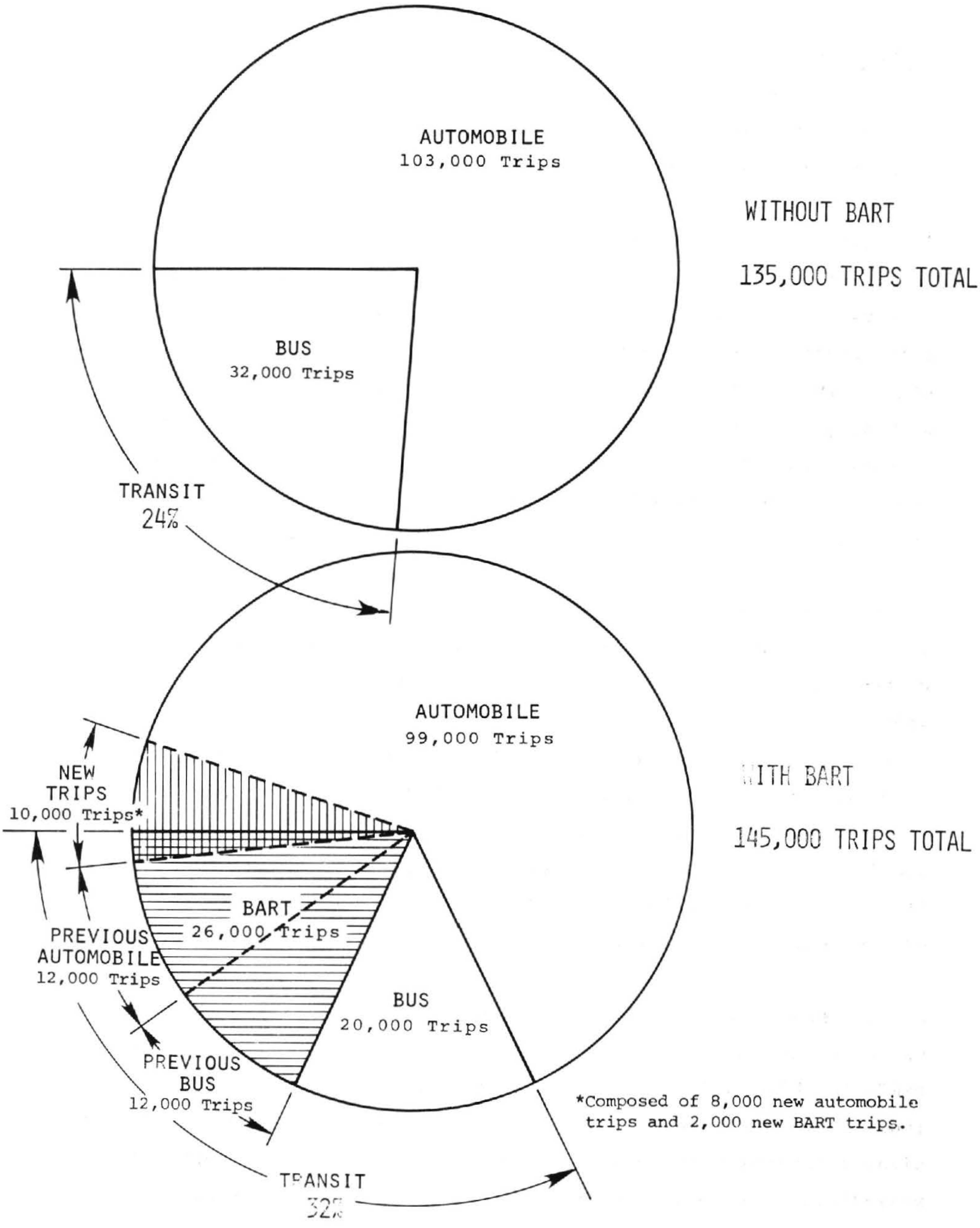
BART's small apparent effect on highway traffic volumes and congestion on the Bay Bridge stems in part from BART's lower-than-predicted ridership.

The low ridership, combined with the relatively high diversion of trips to BART from bus rather than from automobile, has caused fewer cars to be removed than predicted.

But more significant is that new trips by automobile have appeared to fill the road space freed by the diversion of trips to BART. These new trips may be trips that would not have been made at all, or trips that would have been made to different destinations (for example, alternative shopping destinations), given without-BART levels of traffic congestion. In either case, they can be regarded as "induced" automobile trips for the highway in question. In addition, induced trips are now being made on BART itself. Thus, BART, by adding transport capacity in a previously capacity-constrained corridor, has had the effect of allowing (and encouraging) more trips to be made both by transit and by automobile. (These new trips represent gains in mobility and welfare to the people making them.) But BART's net overall effect on highway traffic volumes and congestion has been small.

As summarized in the following figure, the arithmetic of the analysis of total transbay person-trips made by all modes combined, with and without BART, is as follows (taking average trip volumes over the 2 years following the start of transbay BART service): BART's daily transbay ridership of 26,000 trips in each direction was composed of approximately 12,000 trips that, without BART, would have been made by automobile; 12,000 trips that, without BART, would have been made by bus; and 2,000 trips that, without BART, would not have been made at all.

Transbay bus ridership was reduced by 12,000 trips daily, from 32,000 to 20,000 in each direction. Automobile person-trips were also reduced by 12,000 trips daily as a result of diversion to BART, from 103,000 to 91,000; but this loss was offset by 8,000 new automobile person-trips, giving a net loss of only 4,000 automobile person-trips daily (equivalent to roughly 3,000 vehicle-trips daily in each direction). Total person-trips by all modes combined increased from an estimated 135,000 trips without BART to 145,000 trips with BART.



DAILY TRANSBAY TRIPS WITH AND WITHOUT BART

CONCLUSIONS

Applicability of Findings

In drawing implications from the BART experience for the planning of rail rapid transit systems elsewhere, it is important that the findings of this study be viewed in proper context.

BART was conceived and planned to meet some specific objectives, primarily to benefit long-distance commuters to the downtown employment centers of San Francisco and Oakland. Objectives such as conserving fuel, controlling air pollution, or improving the mobility of disadvantaged segments of the population, which are held as important objectives of many present-day public transport improvements, were not emphasized in BART's planning. In assessing BART's performance and in drawing conclusions for other areas, the original BART intents should be kept in mind, as well as current transport planning objectives.

The geography, institutions, and established transportation system of the San Francisco Bay Area, of which BART has become a part, are of course different in many ways from the urban structure of other areas where rail systems are now being considered or developed. At the same time, the Bay Area--with its central-city employment concentrations, older inner-city residential areas, newer distant suburbs, and freeways congested by commuter traffic--has much in common with other large American urban areas. In attempting to apply conclusions about rail transit impacts elsewhere, both the differences and the similarities of the areas must be taken into account.

In this study, BART has been evaluated against the hypothetical alternative transportation system judged most likely to have evolved without BART--in effect a "do-nothing" alternative. BART's impacts relative to those which might have arisen from a high-quality bus system, increased highway construction, or other investments that might currently be under evaluation as alternatives to rail systems in other urban areas, were not analyzed.

The study has documented BART's impacts over the 5-year period since service began, given actual BART service levels and available transportation alternatives. No attempt was made to project what BART's impacts might be in the future under different circumstances.

For all these reasons, conclusions from this BART study should be applied to other areas and in other circumstances with caution. In particular, it is necessary to appreciate how the characteristics of BART, its setting, and the assumptions underlying this study relate to other areas and circumstances. Nevertheless, the findings of this study regarding BART's impacts on travel in the Bay Area have significant implications for those who are now considering or planning investments in rail transit systems in other urban areas.

Implications for Planning Rail Transit

BART's impacts on transportation and travel patterns have generally been smaller than expected by its planners and proponents. But this reflects as much or more on the optimism of the expectations as it does on BART's performance.

Ridership Volumes. Although BART's current ridership of 140,000 trips per day represents a highly significant volume of travel, especially in certain key corridors, it is well below the 260,000 trips per day originally predicted by its designers. This shortfall is explained in part by the shortcomings of current BART service. As the level and reliability of service improves, increases in ridership can be expected. But, even so, it seems unlikely that the original estimates will be achieved as a result of feasible near-term changes in BART service.

The BART experience shows that attracting people to a rail transit system like BART, especially those who would otherwise drive their cars, depends primarily on providing frequent, fast, and reliable service, and convenient access to the rail transit stations. The appearance, comfort, and other qualitative aspects of BART service, though appreciated, are of secondary importance to most travelers.

But the ability of a rail transit system like BART to attract ridership (insofar as this ability is determined by the door-to-door travel times that can be provided), is limited. Even under ideal service conditions, it is necessary for people to get to and from the train station, transfer between vehicles, and wait for trains. Those who are responsible for estimating travelers' mode choice decisions and ridership volumes on another rail system must be careful to make realistic assessments of the level of service that can be provided in practice, and to recognize the intrinsic constraints on the ability of rail transit to attract riders.

Share of Travel. Although BART was intended to be a regional rapid transit system and was largely paid for by people throughout the central Bay Area, BART's share of all trips made areawide is relatively small, amounting to 2% or 3%. Its impacts on areawide vehicle-miles of highway travel and related impacts on fuel consumption and exhaust pollution, are correspondingly small. But these small impacts are all that might reasonably be expected: BART, having only 71 miles of track, should not be expected to have major impacts on an urban area of 330 square miles and a population of 2.6 million people. In this regard, it should be acknowledged that even if BART's ridership were much higher, say at the level of 200,000 trips per day currently targeted by the BART District for long-range future service levels, its areawide impacts would probably not be noticeably different from those so far achieved.

Although its share is small areawide, BART has captured a significant share of trips and has had measurable impacts in a few well-defined travel corridors and for certain kinds of trips. Again, a lesson for other areas is the importance of establishing and publicizing realistic expectations about what a rail system can and cannot achieve, given the complex travel patterns of an established urban area. Realistic estimates of the likely magnitudes of impacts are needed not only by transportation planners and designers, but also by the public and others who must make decisions about the investment of public funds in rail transit.

Highway Traffic Volumes. Even where BART's share of travel is greatest--specifically in the transbay travel corridor--BART has had an apparently small net impact on highway traffic. Perhaps half of all BART's 30,000 daily transbay trips in each direction would otherwise be made by automobile. Thus BART has clearly changed patterns of travel by automobile across the Bay Bridge. BART has also obviously increased total transport capacity in the Bay Bridge corridor. But because the corridor was heavily congested before BART began service (evidencing an excess of travel demand over supply), induced automobile trips have offset those diverted to BART. Thus, BART has allowed or encouraged more transbay trips to be made (thereby benefiting the people making the new trips), with the result that the net change in highway traffic volumes and congestion is very small when with-BART and hypothetical without-BART alternatives are compared.

This conclusion, too, raises the issue of what impacts should be expected from the introduction of new rail transit capacity. The phenomenon of induced traffic should be expected to occur whenever transport capacity is added in a capacity-constrained corridor and no brake on demand is applied, whether the additional capacity is provided by a rapid rail line, a freeway, or any other facility. In planning and predicting the impacts of such facilities, careful attention must be given to estimating the likely volume of induced travel, and the extent to which relieving highway traffic congestion is an attainable objective. Again, it is important that realistic assessments of impacts be made available not only to those responsible for planning and design, but also to the public and other decision makers.

Implications for Rail-Bus Coordination

An issue of concern in planning rail transit systems is the best way in which new rail services can be coordinated with the existing network of bus lines. In attempting to draw implications from the BART experience for planning rail-bus coordination in other areas, it is especially necessary to pay attention to differences and similarities between transit operations in the Bay Area and those in the other areas.

In the Bay Area, the start of BART service has not caused major disruptions to established bus operations, largely because reductions in ridership on bus lines paralleling BART have been offset by increases in ridership on bus lines providing feeder services to the rail stations. The BART experience suggests that in other areas, too, modification of the existing network of bus lines to accommodate the start of rail service may best be achieved gradually by incremental service changes as the patterns of demand for access to the rail system emerge, and as bus capacity is made available from cutbacks in line-haul service where ridership is lost to rail.

In the Bay Area, no single authority is empowered to require cutbacks in bus services that apparently duplicate BART, or to direct any other change in service, such as providing new feeder bus service. Changes in the services provided by MUNI, AC Transit, and other operators instead have resulted from more-or-less independent adjustments made by the various operators in response to changes in demand. Consequently, the BART experience cannot directly address the advantages and disadvantages of pursuing a policy of "forced" rail-bus coordination, as might be proposed in another area with a different set of institutional constraints.

However, the analysis of BART's impacts does show that, except in the few cases where the train exactly duplicates or improves bus service, many people continue to use the bus in preference to BART. An implication is that removal of apparently parallel bus service will, in many cases, remove the availability of the preferred travel alternative, and hence reduce the mobility, of significant numbers of travelers. In planning future systems, these losses in traveler mobility need to be weighed carefully against the cost savings to the transit operator that might be achieved. The overlapping nature of parallel and feeder demand further complicates the question of what level of bus service should be provided, because reducing service on apparently parallel routes (with the intention of increasing BART ridership) may deprive some travelers of their means of access to the rail station (thereby reducing BART ridership).

Potential Future Impacts

Although it was not the purpose of this study to speculate on what BART's impacts might be in the future, or under different conditions of transportation supply and demand, it is evident that many of BART's impacts would be greater if ridership were higher. BART is likely to be most successful in attracting more riders from the bus and automobile by improving reliability and reducing travel times, particularly the time people must spend waiting for and transferring between trains.

BART service is improving and is likely to continue to improve as direct Richmond-Daly City service begins, as headways are reduced, and as reliability is increased. Improved feeder bus services would also decrease access times for some people, and enlarged car parking lots at BART stations would improve access for others. All these improvements would increase BART ridership.

However, large improvements in overall door-to-door BART travel times are indicated as being necessary to achieve significant increases in ridership. For example, analysis of transbay travel mode choices suggests that a 10% reduction in the door-to-door travel time for the average transbay trip by BART--which at 6 minutes implies a substantial improvement in effective BART station-to-station travel times--would increase ridership by something like 5%, other factors remaining unchanged.

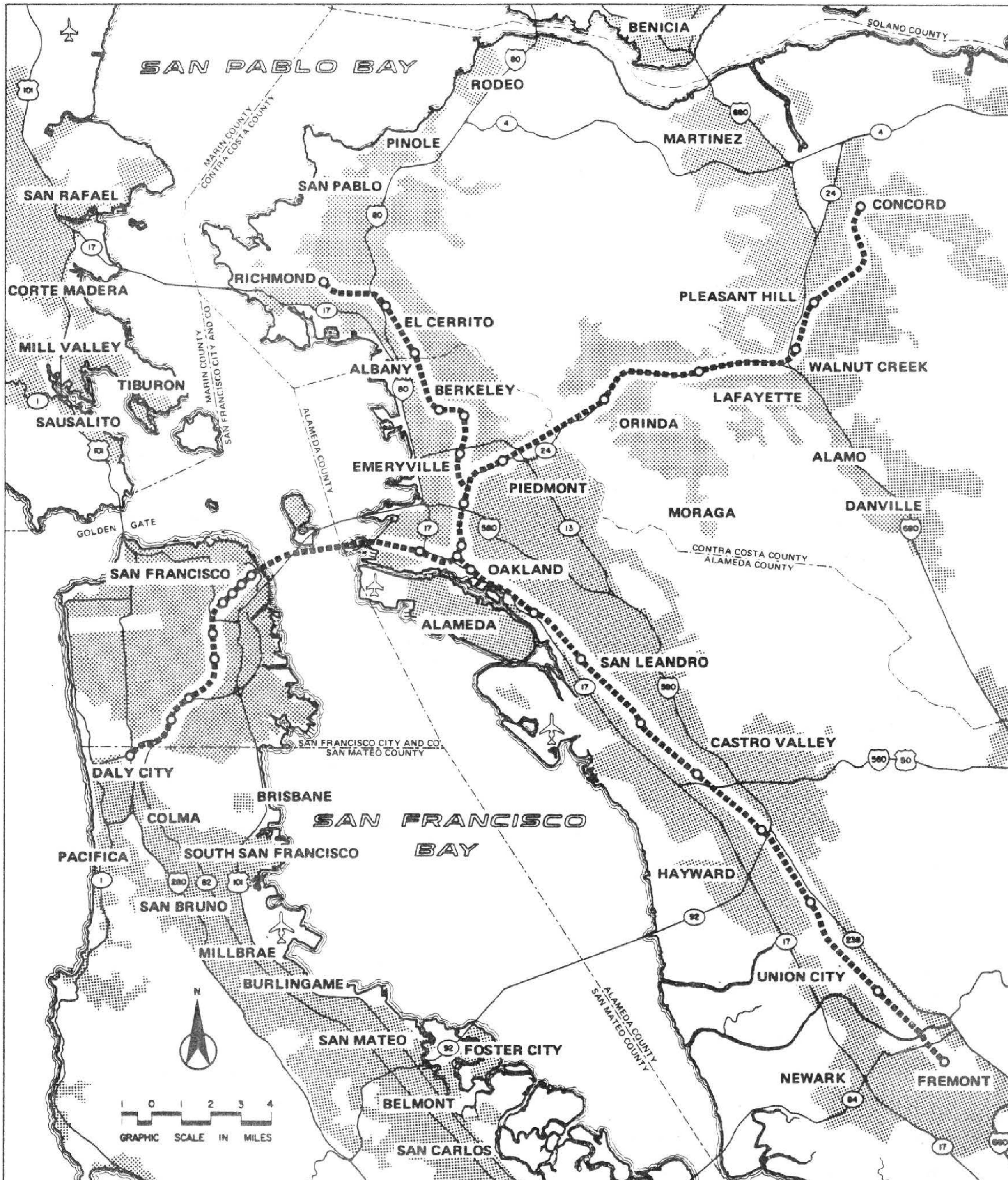
Thus, BART's ridership is largely constrained by the intrinsic limitations of the service it can provide, particularly the requirement that most people must transfer between vehicles in the course of their journeys. Even in combination with improved BART reliability and access facilities, feasible improvements in BART door-to-door travel times would probably not increase BART ridership by enough to change the impacts described in this report in a significant way.

However, the conclusion that only modest increases in BART ridership are likely to result from feasible improvements to BART service is based on several implicit assumptions. In particular, it is assumed that the availability, price, and service offered by bus and automobile remain at approximately their current levels.

Future increases in BART's ridership may depend as much on reductions in the attractiveness of the alternative modes as on improvements to BART service. These reductions may result "naturally" from increasing traffic congestion; or they may result from causes such as increased gasoline prices; or they may result from explicit actions taken by transportation decision makers to regulate the price or supply of the alternative modes (for example, by increasing road use tolls or restraining driving in other ways).

As noted earlier, BART cannot be expected to achieve many of the impacts claimed for it at any likely ridership level. But a potentially high-quality transit system such as BART can have a significant effect on increasing transit use and reducing automobile use in specific travel corridors, especially if accompanied by changes in the price and availability of alternative modes. For example, the existence of BART may permit the transportation decision maker to take actions to restrain private car use that would not be practicable without BART. Potentially, BART's most important impact may be the flexibility it allows for planning and operating transportation in the Bay Area in the future.

INTRODUCTION



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

SAN FRANCISCO BAY AREA RAPID TRANSIT

I. INTRODUCTION

The BART Impact Program

As the first new regional-scale rapid transit system built in the United States in more than 50 years, the San Francisco Bay Area Rapid Transit (BART) System is a potential learning model for metropolitan areas now considering investments in rail transit facilities. BART and its impacts are also of interest to those in the federal government with responsibilities for allocating financial aid for transportation improvements, land use development, and environmental protection in urban areas.

The BART Impact Program is a comprehensive, policy-oriented assessment of the impacts of the BART System. The Program covers the entire range of potential rapid transit impacts with major impact studies of the Bay Area transportation system, travel patterns, land use and urban development, the environment, the regional economy, social institutions and life-styles, and public policy.

The intent of the Program is not to provide a costs-versus-benefits evaluation of the BART investment, nor is it to argue for or against the building of rail rapid transit in other areas. Rather, the intent is to provide an independent assessment of BART and its impacts that will be valuable to transportation planners and designers, the public, and others who must make future decisions about transportation in the Bay Area and other urban areas.

The Transportation System and Travel Behavior Project

This report deals only with the findings of one study within the overall BART Impact Program: the Transportation System and Travel Behavior (TSTB) Project. The TSTB Project assessed the impacts of BART on the characteristics and performance of the transportation system, including bus services and the highway network; traveler responses to BART, such as changes in trip frequencies and mode choices; and the resulting impacts on aggregate travel patterns, trip volumes, and traffic congestion. Findings and conclusions from the TSTB Project will be integrated with the results of the other BART Impact Program studies in the Program's final report, scheduled for publication later in 1978.

Project Scope and Organization*

This is the final report of the 4-year TSTB Project, and its purpose is to summarize findings and conclusions detailed in several earlier Project reports. (A partial listing of these earlier reports is given at the end of this report.) The scope of the TSTB Project is summarized in the following report outline:

THE BART SYSTEM AND SERVICE PROVIDED

Chapter II, The BART System, describes the planning and development of BART, the service provided by the 71-mile, 34-station System, and the costs of building and operating the System.

Chapter III, The BART Service Area, describes the areas and population served by the BART System, the bus, and other transit services operating in the BART service area; the highway network; and travel patterns in the Bay Area.

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*A full explanation of the intent, scope, and methodologies of the TSTB Project research program is given in the TSTB Project Research Plan. (See Reference 4 in the List of References given at the end of the report.)

DETERMINANTS AND NATURE OF BART RIDERSHIP

Chapter IV, Determinants of BART Ridership, analyzes the reasons underlying travelers' mode choice decisions between BART and bus, and BART and automobile, in terms of the travel times and other characteristics of service provided by BART and the alternative modes.

Chapter V, BART Ridership Characteristics, describes the patterns of use of the BART system by line, by time of day, and by purpose; the travel times and other characteristics of BART trips; and the characteristics of people riding BART compared with the characteristics of the BART service area population and the people using other modes of travel.

BART IMPACTS

Chapter VI, Impacts on Modal Split, analyzes BART's share of travel in various corridors and markets, the modal distribution of travel that would likely have occurred without BART, and BART's effects on the overall distribution of travel between public transit and private automobile.

Chapter VII, Impacts on Bus Ridership and Service, assesses the impacts that have resulted from the diversion of travelers to BART from bus and the use of bus by travelers to get to and from BART stations by analyzing increases in feeder bus services, reductions in parallel bus services, and net changes in bus ridership.

Chapter VIII, Impacts on Highway Traffic and Congestion, assesses the impacts that have resulted from the diversion of travelers to BART from automobile--particularly BART's impacts on traffic volumes, congestion levels, and total person-trips by automobile and transit in the San Francisco-Oakland Bay Bridge corridor.

Chapter IX, Implications, summarizes some of the principal conclusions given in earlier chapters and draws implications for planning rail transit.

Basis for Impact Assessment

Assessment of BART's impacts depends, whether explicitly or implicitly, on a comparison of "with-BART" and "without-BART" transportation systems and travel patterns. The with-BART transportation system and the associated travel patterns can be observed directly and, for the most part, are reasonably clearly defined. However, the hypothetical without-BART alternative against which BART impacts are measured is not uniquely defined and must be assumed in the analysis. Conclusions about BART's impacts depend very heavily on the characteristics of the without-BART alternative and the associated travel patterns assumed.

In this report, BART's impacts are judged relative to an assumed without-BART alternative in which bus and highway transportation services are provided at levels close to those existing immediately before the start of BART service in 1972. This hypothetical transportation network has been judged (by BART Impact Program analyses of the Bay Area's recent political and economic history) to represent the transportation system most likely to have evolved by 1976 had BART not been built.*

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*Documentation of the analyses and judgments underlying the definition of this "most likely" without-BART alternative is given in Reference 16.

In some analyses (such as the zone-to-zone travel time comparisons in Chapter IV), the without-BART alternative is defined explicitly as a network of transit lines, service frequencies, highway links, and travel times. In other analyses (such as the highway traffic impact analyses in Chapter VIII), the without-BART alternative is not defined formally in terms of transportation facilities and service levels. However, in all cases, the without-BART baseline for impact measurement, whether explicit or implicit, is essentially the same hypothetical "do-nothing" alternative to the with-BART transportation system.

The assumed without-BART alternative would not provide as extensive transit service as is currently provided by the with-BART system; it would not be capable of carrying current transit ridership; nor would it have required anything approaching the capital investment made in BART. It is important to bear this definition of the without-BART alternative in mind when interpreting the findings and conclusions given in this report. Different hypothetical without-BART alternatives--involving higher investment in improved bus services or highways, for example--would likely lead to rather different conclusions about BART's impacts, but these alternatives have not been analyzed in this study.

The intent in this report is to document the BART experience and assess its impacts to date. It is not the intent to speculate about what the impacts might be in the future when major changes may occur in the availability and cost of alternative transportation modes, and in other factors affecting travel patterns.

Stability of Findings

BART service and ridership have increased over the research period of the TSTB Project and will continue to change in the future. Correspondingly, BART's impacts will continue to emerge and change as time passes. But other aspects of the transportation system and the service it provides have also changed and will continue to change; so, too, have (and will) the many other factors determining travel patterns.

The more time passes, the more difficult it becomes to distinguish the changes in travel patterns which can reasonably be attributed to BART from those which are more likely attributable to factors unrelated to BART. An appropriate time to analyze BART's impacts is long enough after the start of service that its impacts can be considered reasonably stable, but soon enough that conclusions can be drawn with some confidence.

As of the date of this report, BART has been in operation for over 5 years and has provided service on all lines of the System for over 3 years. Service levels have not yet reached those ultimately planned, and ridership continues to grow, so the ultimate level of BART's impacts cannot yet be established. Nevertheless, BART's current ridership of about 140,000 trips per day represents a sufficiently stable level that the nature of its impacts can be assessed with some confidence. At the same time, the period since the start of BART service is still sufficiently short that other factors influencing travel patterns can be accounted for with some confidence, and the assumptions underlying the without-BART alternative remain defensible.

It seems, then, that now--"5 years on"--is as appropriate a time as any to draw conclusions. Even though BART's impacts are continuing to emerge, the nature of the System's effects on the transportation system and travel patterns have largely been established. Subject to the qualifications spelled out in the report, the major conclusions of the TSTB Project will probably not change with likely near-term changes in BART service and ridership.

Travel Surveys and Other Information Analyzed

In the course of the TSTB Project, several interview surveys of travelers were conducted. Four of the most important of these travel surveys, the results of which form the basis for most of the analyses summarized in this report, are:

1974 Transbay Travel Survey
1975 Areawide Travel Survey
1976 BART Passenger Profile Survey
1977 Work Travel Survey

1974 Transbay Travel Survey. The BART Impact Program October 1974 Survey of Transbay Travel, referred to in this report as the transbay travel survey, was a survey of travel by BART, bus, and private automobile in the San Francisco-Oakland Bay Bridge corridor. The survey was conducted by the TSTB Project about 6 weeks after the start of transbay BART service, and consisted of an on-route distribution of questionnaires to transbay BART, bus, and automobile travelers, together with various ancillary control surveys and counts.

A sample of 2,000 responses was analyzed for each of the three modes, representing approximately an 8% sample of trips by BART, 12% of trips by bus, and 2% of trips by automobile. Survey results from the analysis were weighted to reflect different response rates by mode, time of day, and location of questionnaire handout. The survey provides information on the immediate impacts of the introduction of BART service, and, because it was taken soon after the start of service, it provides relatively accurate information on the previous travel patterns of BART riders. On the other hand, the survey results reflect slightly lower BART service levels and ridership than apply currently. Results of the survey are detailed in Reference 5.

1975 Areawide Travel Survey. The BART Impact Program May 1975 Areawide Travel Survey, referred to in this report as the areawide travel survey, was conducted by telephone interviews with a sample of 1,000 respondents drawn from the 1.9 million adult population of the "greater BART service area" defined by Alameda, Contra Costa, and San Francisco Counties and the northern part of San Mateo County (see Chapter III). The survey forms the principal basis for the TSTB Project's analyses of areawide travel. Survey results are detailed in Reference 11.

1976 BART Passenger Profile Survey. The principal source of information about the characteristics of BART riders and their trips is the BART Passenger Profile Survey conducted jointly by the BART District and the BART Impact Program in May 1976. This was a comprehensive on-board survey of BART ridership throughout the System. Over 8,000 questionnaires (representing about a 6% sample) were analyzed. Survey responses were weighted to account for differential nonresponse bias by time of day, station, and ethnic category of BART travelers. The survey results were used to make a detailed analysis of BART's ridership characteristics by purpose, by area, and by socioeconomic stratifications. Survey analysis results are given in Reference 11.

1977 Work Travel Survey. The BART Impact Program 1977 Work Travel Survey (or simply the work travel survey) provides the most recent travel data for the BART impact area and focuses on the principal travel market served by BART: journeys to work. The survey was conducted in June, July, and August 1977. Workplaces were sampled in an area effectively served by the BART lines. The area includes the destinations of virtually all work trips made on BART. Survey questionnaires, distributed to workers at their workplaces, requested information on the mode choices available to them, the characteristics of their journeys to work (both for their usual mode and alternative modes), and the reasons for their travel choices. Responses from over 8,000 workers (representing a 2% sample) were analyzed. Survey methods and results are detailed in Reference 15.

Other Information Sources. In addition to data from the four major interview surveys, information on transportation service levels, traveler behavior, and travel volumes was derived from many other sources. Information analyzed in this report includes (1) computer network estimates of travel times by automobile and transit, (2) results of travel time surveys and observations of congestion delays on key highway links, (3) extensive time-series counts of vehicle and person-trip volumes on key highway links, particularly on the bridges across San Francisco Bay, (4) time-series records of bus ridership and scheduled bus services by line, (5) detailed counts of BART ridership by station and time of day, and (6) several other surveys, including surveys of BART ridership conducted in 1973, 1974, and 1975. These various information sources are documented as appropriate in each chapter and in the other Project reports listed at the end of this report.

THE BART SYSTEM AND SERVICE PROVIDED

II. THE BART SYSTEM

This chapter presents descriptions of the BART System's planning concepts and objectives; its design and operating characteristics, both as they were proposed originally and as they exist now; and the costs of building and operating the System.

Planning Concepts and Objectives*

A report submitted to the BART District** by its engineering, financial, and economic consultants in 1962 contains comprehensive proposals and justification for the present BART System. This report is generally known as the Composite Report (Reference 20).

The dominant theme of the Composite Report and other early planning reports was the concept of BART as a high-quality regional rapid transit system that would offer travel times and service levels competitive with the automobile, particularly for peak-period travel from the more distant suburbs to the central business districts of San Francisco and Oakland. By attracting automobile commuters from their cars, BART was intended to relieve what was projected to be "the continuing increase of highway traffic congestion [which] threatens the future growth and well-being of the San Francisco Bay Area."***

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*A more comprehensive account of the decisions underlying BART's planning and development is given in Reference 17.

**The "BART District" is used in this report to describe both the San Francisco Bay Area Rapid Transit District, the agency responsible for the construction and operation of BART, and the three counties that support BART through sales and property taxes: Alameda, Contra Costa, and San Francisco.

***The perceived need for a rapid transit system and the economic effects and benefits of the System are described in Reference 20, pp. 76-85.

Although improvement of the mobility of people who cannot drive or who do not have access to an automobile, and other transportation benefits, were identified in the Composite Report, these were viewed as secondary. The Composite Report made it clear that BART's primary role was to alleviate peak-period traffic congestion on the San Francisco-Oakland Bay Bridge and other major highways leading to downtown San Francisco and Oakland, and so remove the associated constraints on downtown development, by offering commuters a faster and more convenient alternative to driving.

Thus, BART was conceived primarily as a benefit to commuters, especially long-distance commuters through the "major interurban traffic gateways" leading to the downtown employment centers. The Composite Report estimated that "more than three-quarters of [BART] patrons would be commuters, traveling between home and work, and using the facilities during the critical rush periods." The BART System was not designed particularly to serve short-distance trips within the central cities or nonwork trip purposes. Nor do the original planning reports emphasize other objectives--such as fuel conservation, air pollution control, and improving the travel opportunities of disadvantaged segments of the population--which are held as important objectives of many present-day public transport improvements. In assessing BART's performance, it is necessary to keep in mind the original intents and expectations as well as current transport planning objectives.

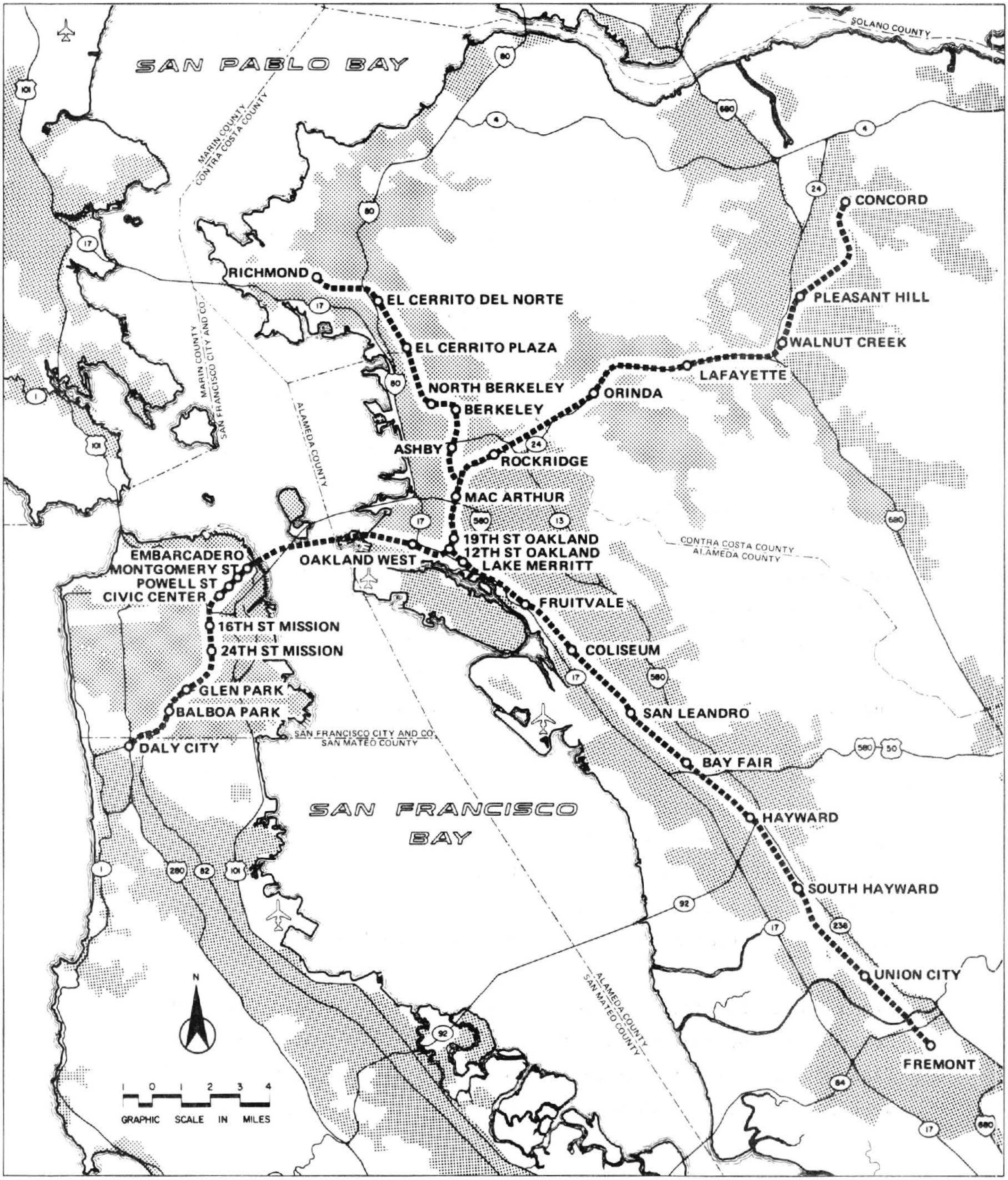
The objective that BART provide fast, comfortable, convenient no-transfer service that would be attractive to automobile commuters translated into a set of stringent design specifications for the System. The requirement that BART travel times be competitive with those by automobile made it necessary to locate suburban BART stations fairly far apart and to have trains with high top speed and acceleration. The requirements that all passengers have a seat and at the same time that adequate peak passenger-carrying capacity be provided made it necessary to have long trains running at short headways. Short headways were also necessary to minimize waiting times. To eliminate the need for travelers going between the East Bay and San Francisco to change trains, the System had to permit merging of trains from all three East Bay lines into the single line running beneath San Francisco Bay.

A lightweight transit car was considered necessary to achieve the required performance with acceptably low power consumption and track maintenance costs. In addition, it was decided to build the BART cars and tracks to a broader-than-standard railroad gauge to increase high-speed stability of the lightweight cars. The design and operating specifications also dictated a fully automated train control system. This was regarded as essential for safe operation at the planned headways and operating speeds, especially to allow merging of trains onto the transbay link.

The bond issue financing the BART System was approved by the voters in 1962. As detailed systems engineering proceeded following the vote, it became clear that existing transit technology could not meet the BART specifications. Consequently, the BART District embarked on a program to develop and produce a new rapid transit car and train control system to meet its specifications. The development and production program has encountered many problems, not all of which have yet been fully resolved. These problems have been well publicized and are documented in Reference 17 and elsewhere. As discussed later, the various problems delayed the introduction of service several years beyond the Composite Report schedule, and they continue to have an adverse affect on the level and reliability of service provided by the System.

Introduction of BART Service

A map of the 71-mile, 34-station BART System is shown in Figure 1. The System lies within the three central Bay Area counties of San Francisco, Alameda, and Contra Costa, except for about 0.2 mile of line and the Daly City BART Station which are in San Mateo County. Four BART lines radiate from the central Oakland section of the System and are identified



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

FIGURE 1

BAY AREA RAPID TRANSIT SYSTEM

by the terminal stations: Daly City in the West Bay, and Richmond, Concord, and Fremont in the East Bay.

BART service was introduced in the following stages:

- September 11, 1972 - Opening of the Fremont Line
- January 29, 1973 - Opening of the Richmond Line
- May 21, 1973 - Opening of the Concord Line
- November 5, 1973 - Opening of the Daly City Line to the San Francisco central business district
- September 16, 1974 - Start of transbay BART service
- November 28, 1975 - Start of evening service, 8:00 p.m. to midnight
- May 27, 1976 - Opening of Embarcadero Station in San Francisco
- November 19, 1977 - Start of Saturday service

BART service is currently provided 6 days a week, from 6:00 a.m. to midnight on weekdays and from 9:00 a.m. to midnight on Saturdays. No service is provided on Sundays. Current scheduled headways between trains are as shown in Table 1. Three direct routes are operated during the daytime: Daly City-Fremont, Daly City-Concord, and Fremont-Richmond. Just two direct services are operated in the evenings: Daly City-Concord and Fremont-Richmond. Passengers who must transfer between routes to complete their journeys (for example, Daly City-Richmond passengers) can do so at any of three central Oakland stations. Weekday daytime headways are scheduled at 12 minutes on each of the three direct routes, giving combined headways of 6 minutes on lines where routes converge (on the Daly City and Fremont Lines, and in central Oakland.)

Train length is varied by route and time of day to match passenger demands; the maximum train length is 10 cars (720-seat capacity). Planned future service improvements include extending the hours of weekday operation to 20 hours (5:00 a.m. to 1:00 a.m.); providing

Table 1

SCHEDULED BART HEADWAYS

Day and Time	Scheduled Headway by Route (Minutes): Daly City -Fremont	Daly City -Concord	Daly City -Richmond	Fremont -Richmond
Weekdays				
6:00 a.m. - 7:00 p.m.	12	12	*	12
7:00 p.m. - 12 midnight	*	20	*	20
Saturday				
9:00 a.m. - 6:00 p.m.	15	15	*	15
6:00 p.m. - 12 midnight	*	15	*	15

	Scheduled Headway by Line (Minutes): Daly City Line (DC-F, DC-C)[a]	Fremont Line (DC-F, R-F)	Concord Line (DC-F)	Richmond Line (R-F)	Central Oakland (DC-F, R-F)
Weekdays					
6:00 a.m. - 7:00 p.m.	6	6	12	12	6
7:00 p.m. - 12 midnight	20	20	20	20	10
Saturday					
9:00 a.m. - 6:00 p.m.	7.5	7.5	15	15	7.5
6:00 p.m. - 12 midnight	15	15	15	15	7.5

*No direct service is provided (with the exception of one train a day in each direction on weekdays). Passengers must transfer between trains to complete their trips.

a. Routes: DC = Daly City; F = Fremont; C = Concord; R = Richmond.

Source: BART District, April 1978.

direct Daly City-Richmond service;* providing Sunday service; reducing headways; and adjusting train sizes to match passenger demands more closely. Both direct Daly City-Richmond service and Sunday service are on the list of improvements intended for introduction in 1978.

BART was planned to open as a total system, with service beginning on all lines simultaneously, but for a number of reasons, the start of service on some parts of the System was delayed, notably the transbay link. Nevertheless, basic weekday daytime service began on all 71 miles of the System within a 2-year period. Although this period was longer than intended, service can still be regarded as having started simultaneously systemwide (at least for the purposes of studying impacts). In comparison, many other rail systems have opened or are currently planned to open in discrete segments over a period of many years.

Since BART began operations there have been continued service improvements. Some of these have been discrete service increases, such as the start of evening or Saturday service; others have been made over extended periods, such as the provision of longer trains, improved bus service to stations, and enlarged parking lots at stations. These gradual improvements are more difficult to monitor, document, and relate to BART's effects on travel patterns.

BART Design and Operating Characteristics

Tracks and Yards. BART's 71 miles of trackway include 20 miles of subway, 24 miles of elevated track, and 27 miles of track at grade or on embankments. Included in the subway portion of the System is the 4-mile long Transbay Tube (between the Oakland West and Embarcadero BART stations) constructed in a submerged trench beneath San Francisco Bay,

*The System has no capability to provide direct service between Richmond and Concord or between Fremont and Concord because anticipated volumes were low.

and the 3-mile long Berkeley Hills rock tunnel (between the Rockridge and Orinda BART stations). Most other subway portions of the System are in the high-density central areas of San Francisco, Oakland, and Berkeley. Subway portions of the System were constructed using a mixture of conventional mining methods, a tunneling machine, and cut-and-cover construction. Fifty-five miles of the System's tracks are adjacent to predominantly residential areas, and 16 miles are adjacent to non-residential land uses.

The BART lines have two tracks, for the most part--one track for trains in each direction. A third "spur" track is provided at five locations for temporary train storage. Special crossovers are installed at 18 locations to permit trains to reverse direction or to operate on the track normally assigned to trains traveling in the opposite direction. Trains travel on broad-gauge (5-foot 6-inch) continuously welded rails fastened to a concrete roadbed. Special rail fasteners provide electrical insulation and dampen vibration.

The BART track layout allows trains on different lines to merge at two places. Near the MacArthur BART station, trains from the Richmond and Concord Lines merge. At the Oakland "wye" in central Oakland, Concord-Daly City and Fremont-Daly City trains currently merge into the transbay link; and Daly City-Fremont trains merge with Richmond-Fremont trains. In the future, when direct service between Richmond and Daly City is provided, trains on three routes will merge at the Oakland "wye."

The BART System has three yards in the East Bay where cars can be inspected, cleaned, repaired, stored, and assembled into trains; there are no yard facilities in the West Bay. The three East Bay yards have a current storage capacity of approximately 470 cars.

Stations. Figure 2 shows the lines of the BART System and the distances between stations. These range from less than 0.5 mile in central San Francisco and Oakland to over 3 miles in outlying low-density areas. The average distance between stations is 2.1 miles.

Of BART's 34 stations, 8 are at grade level, 12 are on elevated structures, and 14 are in subways. All station platforms are designed to accommodate a 10-car train and so are about 720 feet long. The BART stations were designed by 15 different architectural firms and built in a diversity of styles which are generally considered attractive, both by travelers and the communities where they are located. Standards of construction and finish are high (many stations contain artwork), and the areas around all surface stations are attractively landscaped. More extensive landscaping has been provided in a 2.7 mile linear park which extends along a section of aerial track through Albany and El Cerrito. There is also a 0.5 mile stretch of landscaped aerial track in Concord.

With the exception of the downtown Oakland and San Francisco stations, all BART stations are built on two levels, a concourse (entry) level and a platform level. The four subway stations in downtown San Francisco (Embarcadero, Montgomery Street, Powell Street, and Civic Center) have three levels. The lowest level accommodates the BART platform and tracks, the middle level accommodates the new MUNI Metro* platform and tracks, and the top concourse level is shared by both BART and MUNI Metro patrons. The two downtown Oakland stations (12th Street and 19th Street) also have three-level stations; each of the lower levels has a set of BART tracks. The downtown subway stations have several sidewalk entrances, and some also have entrances connecting the concourse with retail stores and offices adjacent to the stations.

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*MUNI Metro, the San Francisco Municipal Railway's new light rail system (not yet in operation) will upgrade the existing streetcar system. The streetcar tracks along Market Street will be replaced by the MUNI Metro subway, which will run above the BART tracks for 1.7 miles and share four stations with BART.

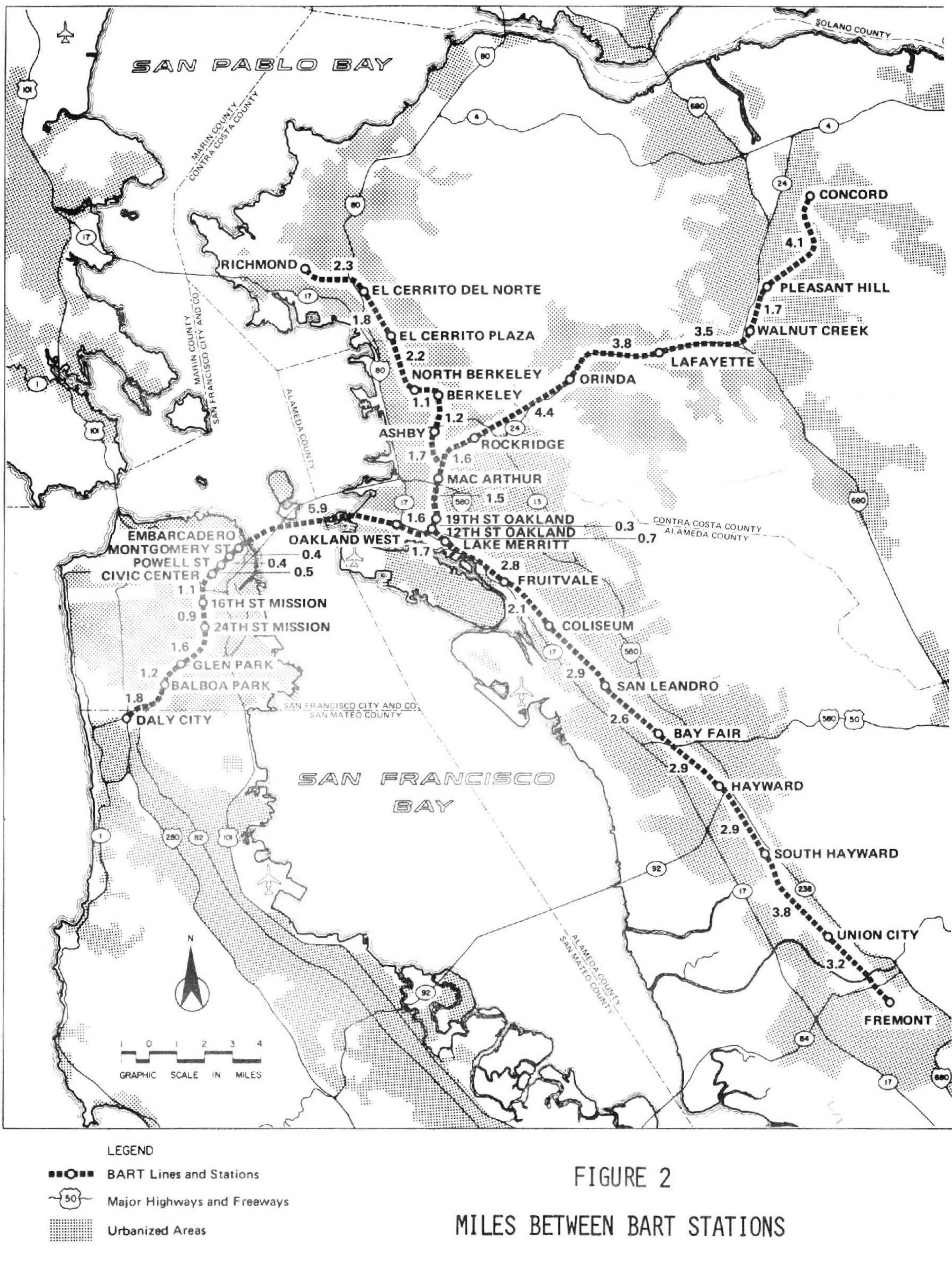

FIGURE 2

MILES BETWEEN BART STATIONS

BART stations have stairs and escalators connecting the concourse and platform levels, one or two elevators (intended primarily for people whose physical disabilities make their use of the stairs or escalators difficult), public restrooms, automatic fare equipment, and machines to issue bus transfer tickets.* All stations also have one or more booths where station agents can monitor TV surveillance screens, activate the elevator, make announcements, permit access to restrooms, and provide other assistance to passengers. Generally, at least one station agent is on duty at all times.

Transit Cars. BART operates two types of cars: "A" cars which have a control cab at one end to house the train attendant and train control equipment, and "B" cars which do not have a control cab. Both types have 72 seats and provide interior headroom of 6 feet 9 inches. "A" cars are 75 feet long and weigh 59,000 pounds; "B" cars are 70 feet long and weigh 57,000 pounds. (A maximum-length, 10-car train consisting of two "A" cars and eight "B" cars is 710 feet long.) Each car is powered by four 150-horsepower motors with propulsion power provided by a 1,000-volt direct-current third rail. The cars are equipped with both a friction braking system and a dynamic braking system (which uses the propulsion motors as generators to return power to the third rail during braking). Acceleration and braking are very smooth.

The cars provide a quiet and very comfortable ride with little vibration or sway. Seats are upholstered, floors are carpeted, windows are tinted, and the cars are air-conditioned. The train attendant uses a public address system to communicate with the passengers.

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*There are currently no bus transfer machines at the Walnut Creek Station, but these will be installed when a BART-bus discount scheme, currently under discussion, is introduced.

Train Performance. BART was designed to operate at maximum speeds of 80 miles per hour with maximum acceleration and deceleration rates of 3 miles per hour per second. Average speeds, counting the time needed for station stops, were to be 45 miles per hour, and headways were planned to be as short as 90 seconds. Various design and operating problems and constraints have prevented these goals from being fully attained.

Maximum scheduled speeds are 70 miles per hour, but close station spacings, curves, and other operating constraints restrict the maximum scheduled speeds on some parts of the System. Under normal conditions, the maximum scheduled speed is 70 miles per hour on outer sections of the Richmond, Concord, and Fremont Lines, and through the Transbay Tube. On the Daly City Line, the maximum scheduled speed is generally 60 instead of 70 miles per hour because of the relatively close station spacings, and maximum speeds are lower still in central San Francisco and Oakland for the same reason. Overall, the scheduled station-to-station speed, including times to load and unload passengers (typically about half a minute per station), averages about 36 miles per hour. Of course, the average speed for a given BART trip will vary significantly from this systemwide average, depending on the origin and destination stations.

The maximum number of trains currently operated on the System during peak periods is 33. In the near future it is planned that this will be increased to 42. BART's central computer facility was recently evaluated and found to be capable of handling no more than 50 trains at one time. Replacement of the BART computer facilities is contemplated within the next several years to make operation of more than 50 trains possible.

With the current 33-train System, trains operate at 12-minute intervals during the daytime on three direct routes. This produces headways of 6 minutes on the Daly City Line (including the Transbay Tube) and on the

Fremont Line. With 50 trains operating on the four planned direct routes, headways on the Daly City Line are expected eventually to be reduced to approximately 3 minutes.

Automatic Train Control.* BART has a computerized, fully automatic train control system that supervises the dispatching, scheduling, and routing of trains. It regulates train speeds automatically and maintains safe distances between trains. It also controls the opening and closing of train doors, the duration of station stops, and the display of information on platform signs; and monitors support facilities, such as fire alarms, ventilators, and pumps.

A number of problems with the train operations system were encountered in the early stages of BART operation, one of which was that, under certain test conditions, the system occasionally failed to detect the presence of a car if all the car's power was turned off. Although this problem was considered extremely unlikely to present any safety hazard during normal operation, the California State Public Utilities Commission required that BART provide an auxiliary system to back up its primary train detection system.

The auxiliary system, called the Sequential Occupancy Release system, employs a series of minicomputers installed in redundant pairs at control points throughout the BART System and automatically checks trains into and out of track sections. Full operation of the Sequential Occupancy Release system, which is still awaiting Public Utilities Commission approval, will permit BART to run trains at headways as low as 2 minutes.

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*A more complete description of the automatic train control system, and some of the problems encountered with it, is given in Reference 8, pp. 27-31.

Fare Collection System. BART fares vary from $0.25 for short trips between stations in central San Francisco or Oakland to $1.45 for travel between the farthest stations on the System. A typical long-distance commute trip from a suburban station to central San Francisco (say the 25 miles from Walnut Creek to Montgomery Street) is $1.25. The average fare paid for all trips made on the System (for an average on-BART trip distance of about 13 miles) is $0.75.

The automatic fare collection system is based on a concept of "stored fare." Passengers can buy tickets at BART stations in any amount from $0.25 to $20.00 and use the same ticket for one or more journeys on the System until its value is used up. Tickets can also be bought at local banks in values of $10.00 and $20.00. People aged 65 and over can buy tickets at a 90% discount (and so pay only 10% of the regular fare). Children aged 12 and under and physically disabled people receive a 75% discount.

After cash (or cash and a previously used ticket with less than $4.00 remaining) is inserted, the ticket vending machine dispenses a plastic coated card on which the value of the ticket is printed and magnetically encoded. Having bought his ticket, the passenger inserts it in the entry faregate to gain access to the platforms. The faregate magnetically encodes the ticket with the time of entry, station of entry, and an entry code which ensures that the ticket is used in the proper sequence, and then returns the ticket to the passenger in about 1 second.

At the exit station, the passenger again inserts the magnetically encoded ticket in a faregate. The faregate automatically reads the code of the origin station, deducts the proper fare, and returns the ticket. If the value remaining on the ticket when it is inserted at the exit faregate is less than the fare for the trip, the ticket is returned, the faregate remains closed, and a sign flashes, indicating that the passenger should go to the add-fare machine to add to the value of the ticket. By inserting the old ticket and the necessary extra cash he can obtain an updated ticket that will allow him to exit. The stations contain changemaking machines.

Associated with the fare collection system is an automatic data acquisition system which records data on BART's ridership from the faregates and transmits the data from exit gates at all BART stations to a central computer. For each exit gate, the system records the number of passengers exiting and their origin and destination stations, and keeps a running total of the data. The data are transmitted to the central computer and accumulated by 1-minute (or longer) intervals.

Reliability of BART Equipment and Service. From the beginning, both the level and dependability of BART service have been adversely affected by unexpectedly high failure rates in many components of the System. Many of these failures have occurred in the components of transit vehicles themselves, particularly propulsion motors and brakes.

In addition to design inadequacies and poor quality control alleged by the BART District to be the root causes of the reliability problems,* several historical factors in the development and manufacture of the technologically innovative and complex BART System have been identified as contributing to the high equipment failure rates.** Among these factors are that (1) designs were based on desired performance specifications rather than on the actual performance characteristics of existing or proven equipment; (2) BART had no experienced operating and

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*A multi-million dollar BART District lawsuit against its engineering consultants and equipment suppliers stemming from these allegations, and counter claims against the District, were settled out of court in July 1977. The settlement is subject to Urban Mass Transportation Administration approval of the BART District's request for reimbursement of part of its settlement payment.

**These historical factors are documented in Reference 17, pp. 170-176.

maintenance departments capable of responding to the designs proposed by the engineers and manufacturers, and (3) manufacturers' prototypes were not subjected to full-scale testing before the equipment was produced. BART has also encountered significant difficulties in maintaining and repairing the transit vehicles in a timely manner because of shortages of spare parts and other factors.

As a result of the unexpectedly high failure rates and the problems encountered in repair and maintenance, BART has, until recently, had difficulty in making sufficient cars available to provide desired service levels. Equipment problems have also resulted in frequent in-service train failures (often requiring the off-loading of passengers and removal of trains from service) and, at the requirement of the State Public Utilities Commission, have necessitated reduced train speeds in rainy weather. Although BART has diverted considerable resources to remedying these problems and has been successful in improving car availability and other indicators of reliability, the System continues to be plagued with delays. As discussed later in the report, these delays have given rise to a widespread perception of BART as undependable, with consequent impacts on peoples' willingness to ride the System.

<u>Parking at BART Stations</u>. Twenty-three of the 34 BART stations have parking lots, with between 200 and 1,600 parking spaces at each lot. In the West Bay, only the terminal Daly City Station provides off-street parking (1,600 spaces). In the East Bay, all but three stations (the two downtown Oakland stations and Berkeley) have parking lots. The total parking capacity at all BART stations is currently 20,300, an increase of 2,200 spaces over the capacity at the time transbay BART service began in 1974. The current total, however, is still considerably lower than the 36,000 spaces proposed in the 1962 Composite Report, largely because cutbacks were made during BART's construction to save costs.

The 2,200 spaces added over the last 3 years were provided in response to shortages of parking space at several stations, notably stations on the Concord Line, the southern part of the Fremont Line, and at Daly City. However, these added spaces have not removed the capacity constraints; parking lots at these stations are typically filled as early as 7:30 a.m. BART riders also park on city streets for a considerable distance around many of these stations.

All but one of the BART stations with parking spaces reserve some spaces for midday parking; a total of about 1,600 such spaces are provided at 22 stations. The midday parking facilities accommodate BART passengers traveling between 9:00 a.m. and 4:00 p.m. Provision is also made for people being dropped off or picked up by car at the stations, but such "kiss-and-ride" facilities are not a major feature of BART station design. There is currently no charge for parking in BART station lots, except at the Lake Merritt Station in Oakland, where a small charge ($0.25) is levied to discourage parking by students from the adjacent college.

BART Capital Costs*

The capital costs of building BART and putting it into operation are summarized in this section. The original cost projections are compared with the actual final capital costs, and the reasons for the difference between the two are explained. The impacts of BART's capital expenditures on the Bay Area economy are not discussed here, but are analyzed in another BART Impact Program report (Reference 18, pp. 13-44).

Capital cost estimates in this section are for construction of the entire BART System (71 miles, 34 stations), including maintenance shops,

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*A more detailed analysis of the components of BART's capital costs, and documentation of the results summarized here, is given in Reference 13.

yards, the train control system, and the BART administration building; 450 BART cars; and facilities for MUNI Metro.* Also included are expenses associated with testing and putting BART into operation. Information on actual costs is derived primarily from the BART Capital Program Report of September 1975 (Reference 24), which gives both costs expended to date and estimated final costs.

Comparison of Actual and Forecast Capital Costs. Actual final capital costs for the BART System are estimated to be $1,636 million. At the time of the September 1975 report, $1,517 million or 93% of the total amount had been expended. The remaining amount is for further car testing and modification, further work on the train control and power distribution systems, additional parking facilities at certain BART stations, completion of MUNI Metro facilities, and various other construction projects. It is presumed for the purposes of this analysis that all remaining capital costs will be incurred by 1980, although in reality capital expenditures for modifications to the System will continue after that date.

In the 1962 Composite Report (Reference 20) it was forecast that BART would cost $994 million. This original forecast, and its components, are compared to estimated actual costs in Table 2. Actual costs in Table 2 are not adjusted for inflation.

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*The new MUNI Metro light rail system will operate in a new subway beneath Market Street on a level immediately above the BART tracks for 1.7 miles, and will share four stations with BART (Embarcadero, Montgomery Street, Powell Street, and Civic Center). Beyond Civic Center, MUNI Metro will run through a new 1.5 mile subway from Civic Center to East Portal (including three stations), through the existing 2.4 mile Twin Peaks Tunnel, and along 0.1 mile of track at West Portal Station. The BART capital cost total includes an estimated $155 million for facilities that will be used exclusively by MUNI Metro.

Table 2

FORECAST AND ACTUAL BART CAPITAL COST COMPONENTS
(All Costs in Millions of Dollars)

Cost Component	1962 Composite Report Forecast	Actual Expenditure	Increase (Decrease)
Track and Structures	$459	$ 663	$204
Stations	134	332	198
Yards and Shops	14	23	9
Electrification	65	37	(28)
Train Control	23	52	29
Utility Relocation	48	35	(13)
Right-of-Way	99	104	5
BART Transit Vehicles	71	175	104
Engineering and Management	74	137	63
Preoperating Expenses	7	78	71
Total	$994	$1,636	$642

Note: Actual expenditures for the various cost components were estimated by summing the amounts of individual BART contracts. Sometimes these contracts covered items in more than one component, so a precise allocation was not possible. In particular, some station construction contracts included tunneling part of the line between stations. Consequently, the station cost total shown is slightly overstated, and track and structures costs are correspondingly understated. Additional documentation is given in Reference 13, p. 5.

Sources: References 20 and 24.

As shown in the table, the largest proportionate variances between actual and forecast costs are for preoperating expenses, station construction, and transit vehicle costs. In absolute terms, the largest cost variances are the $204 million increase in construction costs for track and structures, and the $198 million increase in construction costs for BART stations.

BART's actual final capital cost of $1,636 million is $642 million or 65% greater than the original 1962 forecast. The amount of this apparent overrun is of historic interest only. However, the reasons for the increase are relevant to the planning of future transit systems. Three major factors can be identified:

1. Changes in scope from that originally specified in the Composite Report

2. Actual inflation at rates higher than anticipated in the Composite Report

3. Alterations to the original construction and implementation schedule

Cost Increases Resulting from Changes in Scope. Scope changes include (1) construction of facilities not anticipated in the original Composite Report System (e.g., the Embarcadero Station and the subway line in Berkeley), (2) upgrading of facilities included in the original System (e.g., enlarging stations and adding escalators and facilities for physically disabled people), and (3) work required by others to permit BART construction to continue (e.g., extensions to the concourses of downtown San Francisco stations). The total increase in capital costs resulting from scope changes (including costs attributable to inflation and any delays associated with the scope changes) is estimated to be $180 million.

Cost Increases Resulting from Unanticipated Inflation. In formulating the Composite Report capital cost forecast, the influence of inflation was anticipated, and an allowance was included to compensate for its effects. The Composite Report allowance, based on a review of historical inflation rates prior to 1960, was a constant inflation rate of 3% per year. However, as shown in Figure 3, actual inflation rates since 1962 have been considerably higher than the Composite Report allowance, averaging almost 8% per year over the period 1964-1973 when nearly all BART construction took place. Correspondingly, costs encountered during construction of the BART System have been very much higher than anticipated.

According to the analysis of this study, it would have cost an extra $106 million to build BART, as a result of higher-than-anticipated inflation alone (assuming no changes in the scope of the originally planned project and the same construction schedule anticipated in the Composite Report).

Cost Increases Resulting from Schedule Delays. BART's planners originally estimated that it would take about 6 years to build the major elements of the System. It actually took nearly 11 years. Among events that caused major delays were: (1) taxpayer's court suit challenging the 1962 election, which delayed the entire project by about a year; (2) negotiations with cities concerning BART routing, design features, and station plans which were much more extensive than anticipated; and (3) a shortage of funds between 1967 and 1969 which necessitated lengthy delays while additional funds were sought.

The analysis of this study suggests that if, hypothetically, future inflation rates had been known in 1962, the Composite Report would have estimated the total cost of BART to be $1,100 million. This estimate assumes no changes in scope, the same construction schedule as given in the Composite Report, and no allowance for contingencies (other than

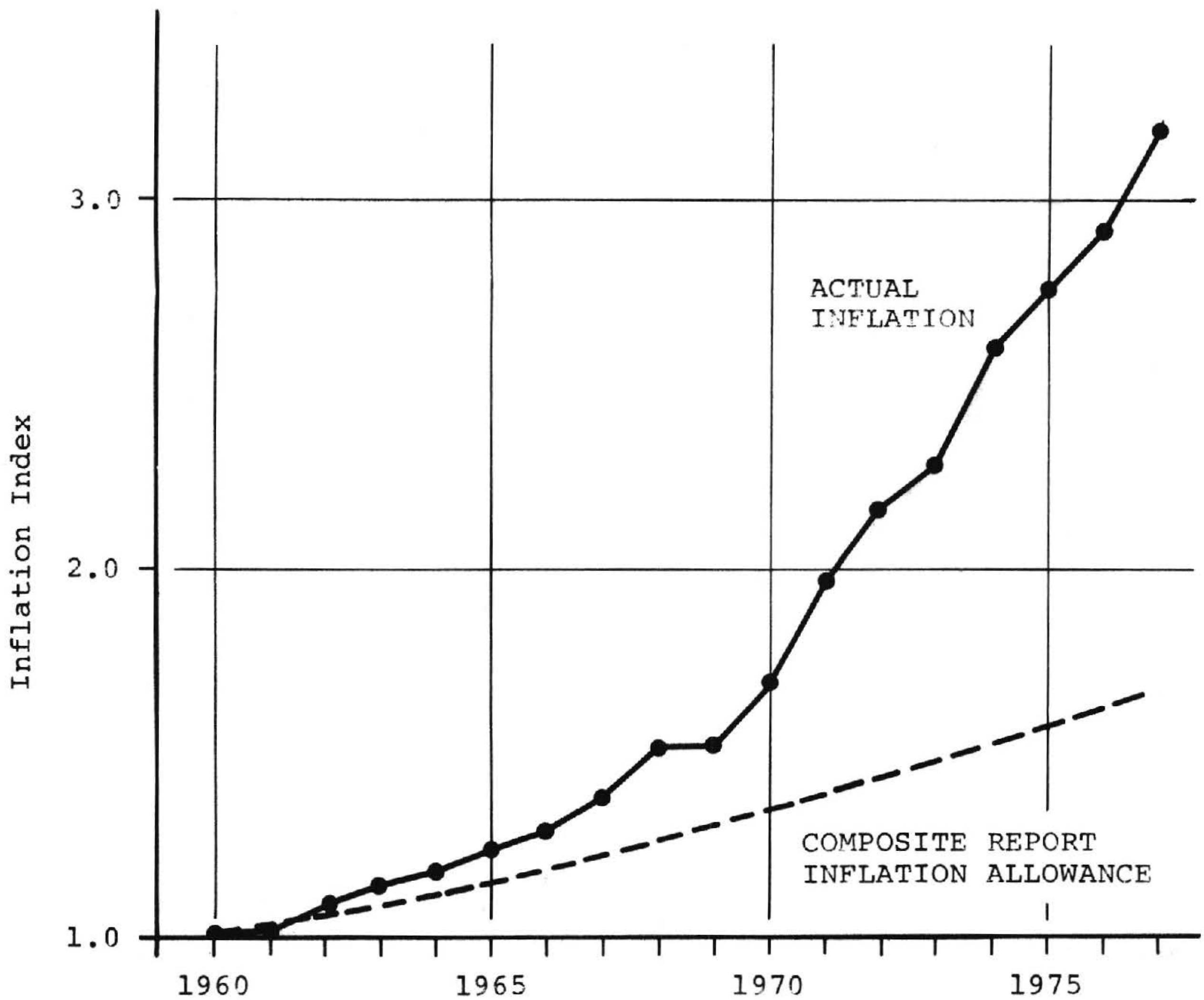

FIGURE 3

FORECAST AND ACTUAL INFLATION 1960-1977

Source for Actual Inflation Rate: Engineering News-Record Index of Building Construction Costs for San Francisco inflation). If both the actual future inflation and the actual schedule of construction had been known in 1962, the Composite Report would have estimated the total cost of BART to be $1,453 million (again making no allowance for scope changes or contingencies). The difference between the two estimates, $363 million, is the portion of the cost overrun attributable to delays, given actual inflation.

Summary of Variance Between Actual and Forecast Costs. An analysis of the $642 million increase in BART's capital cost is summarized in Table 3. The cost increase associated with "changes in scope," "inflation presuming no delays," and "inflation due to delays," totals $648 million. This compares with an allowance of only $74 million made for contingencies in the Composite Report. The difference, $574 million, accounts for 89% of the total $642 million variance.

The Composite Report contingency allowance of $74 million is shown as a negative 12% in the fourth column of Table 3. If this amount is distributed among the cost categories of "inflation presuming no delays," "inflation due to delays," and "changes in scope" in proportion to the amounts given in the third column of the table, then an adjusted percentage distribution is obtained, as given in the final column of the table. This final column probably gives the most meaningful summary explanation of the reasons for the $642 million capital cost variance between forecast and actual BART capital costs:

- 50% ($321 million) is explained by the costs of inflation associated with delays

- 25% ($159 million) is explained by scope changes

Table 3

VARIANCE BETWEEN FORECAST AND ACTUAL BART CAPITAL COSTS
(All Costs in Millions of Dollars)

	1962 Composite Report Forecast	Actual Expenditure	Increase (Decrease)			
			Amount	Percent of Total	Adjusted Amount[a]	Adjusted Percent of Total
Basic System and Transit Vehicles[b]	$750	$ 818	$ 68	11%	$ 68	11%
Composite Report Contingency Allowance	74	—	(74)	(12)	—	—
Inflation Presuming No Delays	170	276	106	17	94	14
Inflation Due to Delays	—	362	362	56	321	50
Changes in Scope	—	180	180	28	159	25
Total	$994	$1,636	$642	100%	$642	100%

a. Contingency allowance of $74 million distributed among "inflation presuming no delays," "inflation due to delays," and "changes in scope" in proportion to amounts given in column 3 for these three cost categories.

b. Includes all cost components listed in Table 2.

Sources: References 20 and 24. Additional documentation is given in Reference 13, page 5.

- 14% ($94 million) is explained by the effects of higher-than-anticipated inflation

- 11% ($68 million) is explained by factors other than inflation, delays, and scope changes

The "other" factors explaining the $68 million include deficiencies in the original Composite Report cost estimates and shortcomings in the way the project was conducted and managed. However, they may also include effective scope changes not identified in this analysis.* And of course the $68 million estimate reflects several other assumptions made in the analysis. Given these uncertainties, the "other" component of the total cost overrun can be regarded as relatively small in the context of the overall $1,636 million BART project, and reflects favorably on the accuracy of the original engineering estimates.

The $94 million cost variance attributable to higher-than-anticipated inflation (in the absence of delay) is not one that could have been avoided without benefit of prescience. However, it is noteworthy that, in spite of inflation rates actually being much higher than predicted in the Composite Report, the $94 million amount contributes only a relatively small part (14%) of BART's total apparent cost overrun.

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*For example, as noted in the BART District Annual Report for 1975-1976, the District has capitalized $25 million of the operating expenses incurred from 1966 through 1975, before "full-system" operations. To the extent that the Composite Report did not make allowance for the extended startup period associated with these expenses, the $25 million amount may be considered a result of a scope change. Transferring $25 million from line 1 of Table 3 ("basic system and transit vehicles") to line 5 ("changes in scope") to reflect this view changes the last column of the table slightly to show the following explanation of the variance between forecast and actual BART capital costs: basic system and transit vehicles, 7%; inflation presuming no delays 15%; inflation due to delays, 50%; changes in scope, 28%.

Much more important are the other two factors analyzed--inflation associated with delays to the construction and implementation schedule, and changes in project scope--which together account for $480 million or 75% of BART's apparent overrun.

Conclusions. Much of the $480 million variance caused by delay-related inflation and changes in scope could have been avoided or anticipated had BART's planning and construction been conducted differently. For example, many of the delays to BART's construction schedule arose from protracted negotiations with cities and local agencies, and many of the scope changes resulted from these negotiations. Had it been possible to conduct the negotiations and reach agreements before setting the construction scope and schedule, a more reasonable schedule (with associated cost estimates) could have been established and subsequent delays (and cost increases) avoided.

The circumstances of BART's decision history were such that agreements were not reached with local communities and agencies before the project scope, schedule, and cost estimate were established, and delays to the established schedule subsequently arose from many different causes. The circumstances of other projects will be different from BART's and will impose different sets of constraints. However, a conclusion from the BART experience, which is probably true in general, is that minimizing delays to an established project schedule is likely to be a major factor in minimizing the variance between actual and forecast costs. Obviously, this is a matter of (1) establishing realistic, attainable schedules for construction and implementation, and (2) managing the project so as to avoid delays to the schedule, once established.

BART Operating Costs and Revenues

BART's operating costs and revenues, and their components are summarized in this section, and some comparisons with the costs and revenues of other transit operators are made. However, the costs and revenues associated with operating the BART System are not compared explicitly with those of the hypothetical without-BART alternative transportation system. This comparison is included in the analysis of the economic and financial impacts of BART's operations documented in Reference 18, pp. 45-64.

BART's operating expenses totaled $70,268,000 in the fiscal year ended June 30, 1977. Table 4 shows the distribution of this total by five cost components: (1) transportation, (2) maintenance, (3) police services, (4) construction and engineering, and (5) general and administrative. Operating expenses net of capitalized costs were $66,814,000.

Reflecting BART's continuing efforts to overcome problems with its cars and train control equipment, almost half of BART's total operating expense is for System maintenance. This is a much higher percentage than is typical of other transit systems. For example, only about 25% of the Chicago Transit Authority's rail operating costs are for maintenance, even though its equipment is much older. It has always been supposed that when BART overcomes its "startup" problems, its high maintenance costs will decrease. However, no such decrease is evident to date.

As shown in Table 5, BART's passenger fare revenues (net of discounts and other deductions) were $24,692,000 for the fiscal year ended June 30, 1977. Fare revenues thus covered 37% of net operating costs.*

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*Meaningful comparison of revenue-to-cost operating ratios among different Bay Area transit operators is difficult, given the different nature of their operations and the different accounting methods employed. However, analysis of operating costs and revenues for the two major Bay Area bus system operators suggests that their operating ratios are broadly similar to BART's.

Table 4

BART OPERATING COSTS, 1976-1977

Operating Cost Component	Amount	Percent
Transportation	$ 17,982,000	25%
Maintenance	32,888,000	47
Police Services	2,114,000	3
Construction and Engineering	5,434,000	8
General and Administrative	11,850,000	17
Total Operating Costs	$ 70,268,000	100%
(Capitalized Costs)	$ (3,454,000)	
Net Operating Costs	$ 66,814,000	
Annual Passenger Trips	$ 34,599,000	
Annual Passenger Miles	444,401,000	
Net Operating Cost per Passenger Trip	$1.93	
Net Operating Cost per Passenger Mile	$0.15	

Source: BART District Annual Report for Fiscal Year ended June 30, 1977.

Table 5

BART OPERATING REVENUES, 1976-1977

Operating Revenue Component	Amount	Percent
Net Passenger (Fare) Revenues	$ 24,692,000	35%
Other Operating Revenues	1,466,000	2
Sales Tax Revenues	31,526,000	45
Property Tax Revenues	5,521,000	8
Federal Operating Assistance	3,400,000	5
State and Local Operating Assistance	384,000	1
Construction Funds	3,279,000	4
Total Operating Revenues	$ 70,268,000	100%
Annual Passenger Trips	34,599,000	
Annual Passenger Miles	444,401,000	
Net Fare Revenue per Passenger Trip	$0.71	
Net Fare Revenue per Passenger Mile	$0.06	

Operating Ratio

Net Passenger Revenues ÷ Net Operating Costs = 0.37

Source: BART District Annual Report for Fiscal Year ended June 30, 1977.

As shown in Table 4, BART's operating cost per passenger is $1.93, considerably higher than for most other U.S. rail transit systems. However, BART's average trip length of about 13 miles is also longer than is typical, so the per-passenger-mile cost of $0.15 is not much different from the per-passenger-mile operating cost of other rail systems.

The operating cost estimates given in Table 4 do not include any allowance for repayment of the capital cost of building BART. Amortizing BART's total capital cost of $1,636,000,000 over 50 years at an interest rate of 5% per year, for example, gives an annual payment of $82,593,000. At 1976-1977 ridership levels, this payment is equivalent to $2.39 per passenger trip or $0.19 per passenger mile, substantially more than current operating costs.

III. THE BART SERVICE AREA

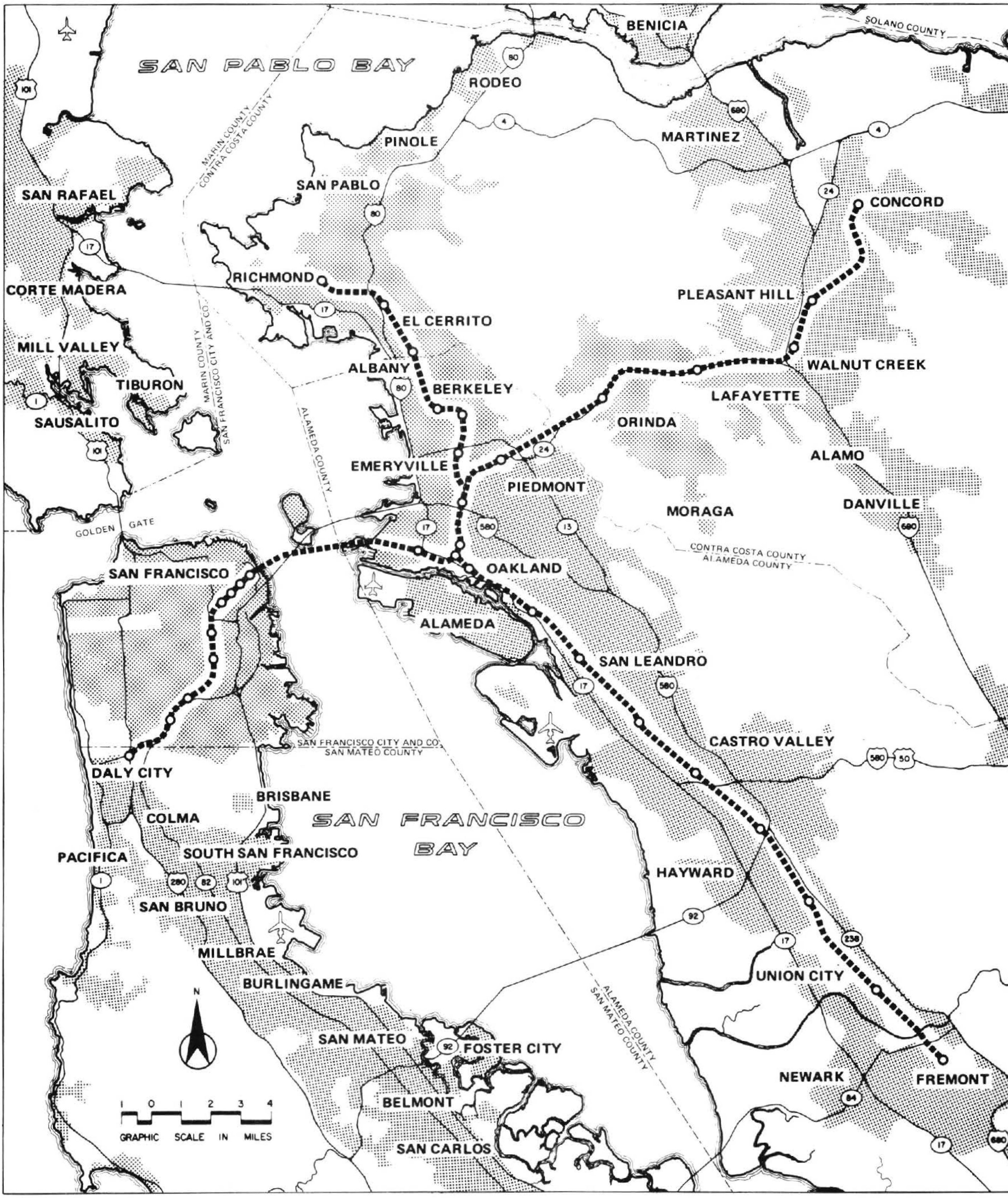
This chapter presents descriptions of the areas served by BART and the characteristics of their populations; the other Bay Area transit services and their relationships to BART; the highway system; and overall travel patterns in the BART service area.

The BART Setting

The San Francisco Bay Area is characterized by natural barriers which have constrained the area's settlement patterns and defined its transportation needs. The first barrier, San Francisco Bay, divides the area into three land masses: the San Francisco Peninsula or the "West Bay"; Marin County to the north across the Golden Gate from San Francisco; and Oakland, Berkeley, and other urban and suburban areas of Alameda and Contra Costa Counties, or the "East Bay." Hills form barriers in several places: the coastal range on the peninsula south of San Francisco and in Marin County; and the Berkeley Hills running along the northeastern boundary of the East Bay coastal plain area. These topographic barriers have channeled urban development and formed fairly well-defined transportation corridors, as suggested by the patterns of urbanization shown in Figure 4.

The four lines of the BART System radiate from central Oakland in Alameda County and follow major transportation corridors. In the East Bay, the Richmond Line runs north from Oakland through the university city of Berkeley to the middle-income suburb of El Cerrito and the city of Richmond in Contra Costa County. Richmond has predominantly low-income and black minority residential areas, and a significant amount of blue-collar employment.

From Oakland to the east, the Concord Line runs through Oakland's inner suburbs and through the Berkeley Hills tunnel to the generally affluent and white residential suburbs of Orinda, Walnut Creek, Concord, and other cities in central Contra Costa County.



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

FIGURE 4

THE BART SETTING

To the southeast, the Fremont Line runs from downtown Oakland through the predominantly low-income black residential areas and employment centers of southeast Oakland; the industrial areas of San Leandro; and the generally low-density, middle-income residential suburbs of Hayward and Fremont in southern Alameda County.

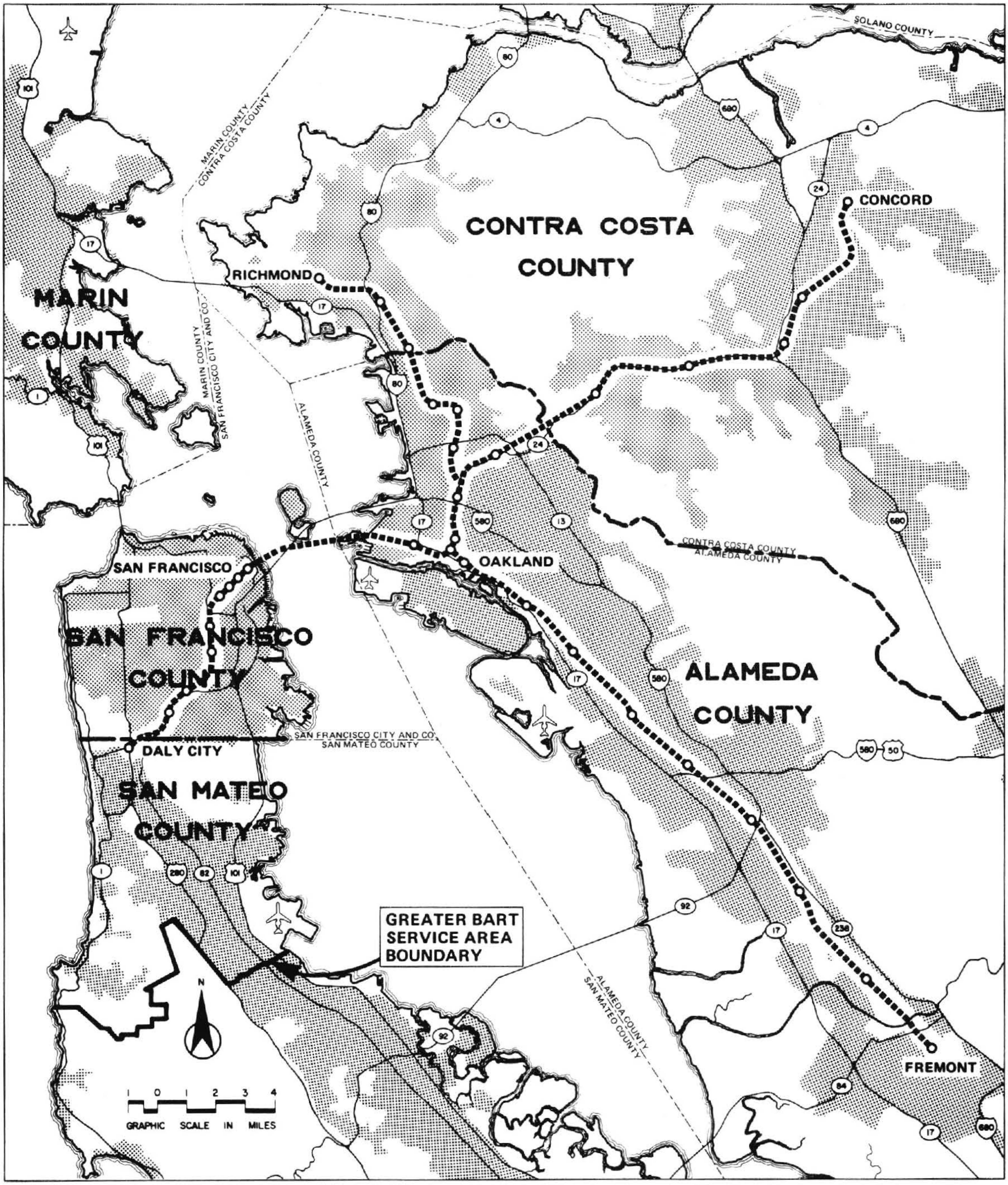
West from downtown Oakland, BART runs under San Francisco Bay to the City and County of San Francisco, where four stations serve the central business and financial districts of the City. The line then runs through the Spanish-American Mission District and the middle-income residential areas of outer San Francisco to the terminal station of Daly City, a quarter of a mile over the county line in San Mateo County.

Seventeen of the System's 34 stations are in Alameda County, eight are in Contra Costa County, seven are in San Francisco, and one (Daly City) is in San Mateo County.

Definition of BART Service Areas

The area effectively served by BART is not amenable to precise definition. Consequently, several different areas are defined as the basis for the analyses given in this report. The nine-county San Francisco Bay Region has been divided into 440 geographic zones for transportation analysis purposes. These 440 zones form the elements defining the various BART service areas (and the basis for most other geographic analyses described in the report).

The greater BART service area is defined by a 239-zone area comprising the three BART District counties of Alameda, Contra Costa, and San Francisco (the tax-supporting BART District) plus the northern part of San Mateo County (cities of South San Francisco, San Bruno, Brisbane, Colma, Daly City, Pacifica, and Millbrae). Most of the urbanized portions of the greater BART service area are shown in Figure 5. However, a few suburban areas of eastern Alameda and Contra Costa Counties are not shown. Figure 9 (given later in this chapter) shows the full extent of these areas.



LEGEND

- BART Lines and Stations
- (50) Major Highways and Freeways
- Urbanized Areas

FIGURE 5

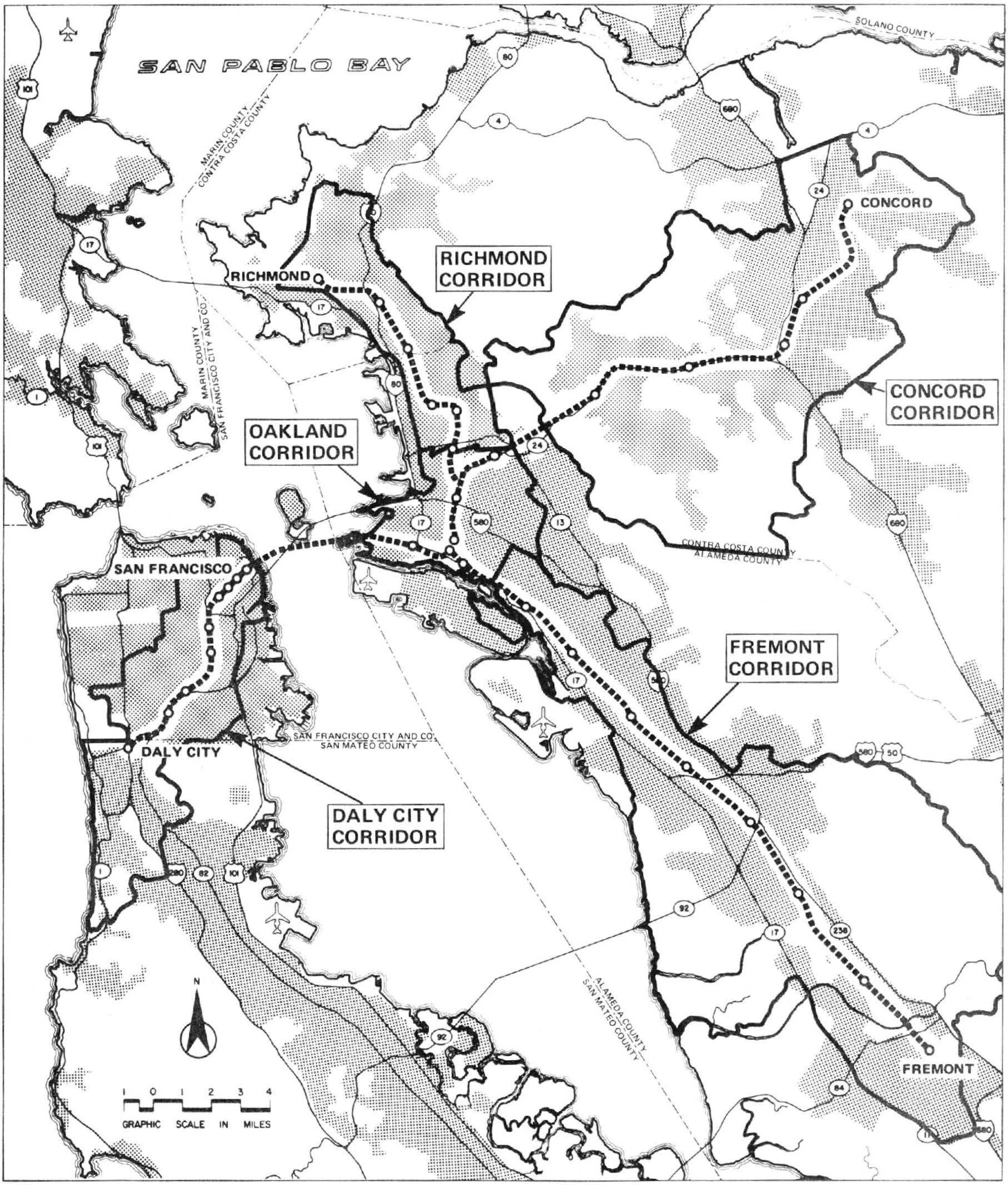
GREATER BART SERVICE AREA

The greater BART service area is the area surveyed in the 1975 areawide travel survey, and for practical purposes encompasses all parts of the Bay Area even remotely served by BART. (The area currently accounts for the origins of 96% of all BART riders.) Analyses given in the report, which refer to "areawide" travel patterns or impacts, are generally for this greater BART service area.

The three BART District counties of Alameda, Contra Costa, and San Francisco are defined by 218 zones (the greater BART service area less 21 zones in northern San Mateo County). The approximate greater BART service area defined by the three counties has been used in some analyses where data are only available summarized by county. The three-county area accounts for the origins of 85% of BART riders. Aggregate characteristics of the greater BART service area and the three-county area are similar.

The 132-zone primary BART service area, outlined in Figure 6, defines a more immediate BART "catchment" area. The area was selected by analyzing the number of BART riders originating from each zone in the greater BART service area relative to the zone's total population and urbanized land area. The primary BART service area accounts for the origins of 80% of all BART riders and is taken as the basic BART impact area for many of the analyses reported. For analysis purposes, five BART corridors have been defined (Daly City, Richmond, Concord, Fremont, and Oakland), as shown in Figure 6. These corridors approximate the catchment areas of the various BART lines.

An 88-zone sampling area was defined for the work travel survey, as shown in Figure 7. This is referred to as the work travel survey area and defines an area containing workplaces that are readily accessible by BART. (The area is smaller than the primary BART service area because people generally travel shorter distances from BART station to workplace than from home to BART station.) Within the work travel survey area, seven subareas are defined (San Francisco central business district (CBD), Other San Francisco, Oakland CBD, Other Oakland, Richmond Line, Concord Line, and Fremont Line), as shown in the figure. All data given



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

FIGURE 6

PRIMARY BART SERVICE AREA

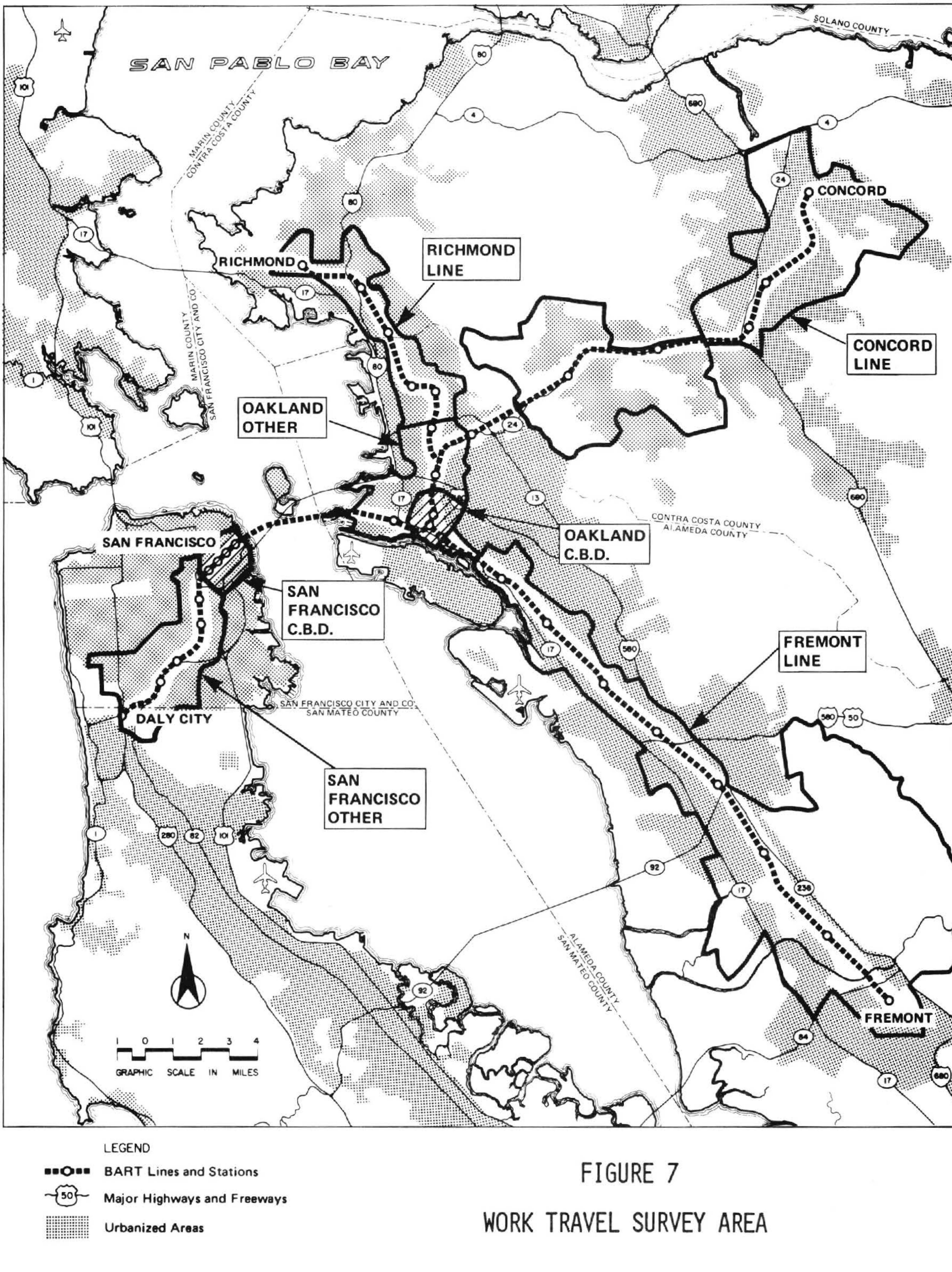


FIGURE 7

WORK TRAVEL SURVEY AREA

in the report for the work travel survey are for journeys to workplaces in the areas shown.

BART Service Area Populations*

Greater BART Service Area. The greater BART service area covers nearly 1,600 square miles, of which about 330 square miles are urbanized. In 1975 the area had a population of 2,574,000, or 0.3% more than the 1970 population of 2,565,000. U.S. Census data for the greater BART service area population are summarized by county in Tables 7a and 7b at the end of the chapter. Table 7a shows data for the total population; Table 7b shows data for the population aged 16 and older (the age group surveyed in the 1975 areawide travel survey and the 1976 BART passenger profile survey).

Primary BART Service Area. The primary BART service area covers 322 square miles, most of it developed. The population was 1,620,000 in 1970 and 1,606,000 in 1975, a decline of 0.9% over the 5 years. Growth is occurring in the San Francisco Bay Region as a whole. However, most of the growth is to the south and north, outside both the greater and the primary BART service areas. Except for the outer stations on the Fremont and Concord Lines, BART does not run through new high-growth areas.

Population data for the primary BART service area and its five component corridors are summarized in Table 8 at the end of the chapter. Comparison of Tables 7a and 8 shows that the primary BART service area has a slightly higher percentage of minorities than the greater service area. Black and Spanish-American residents make up about 14% and 14%, respectively, of the primary service area population, compared with 12% and 13%, respectively, of the greater service area population. Correspondingly, the mean family income (based on 1969 figures) is slightly lower in the primary service area ($12,300) than in the greater service area ($12,800).

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*Further details on the different BART service area populations are given in Reference 11.

Daly City BART Service Corridor. The Daly City corridor shown in Figure 6 covers an area of 36 square miles, including dense urban development in older areas of San Francisco and less dense development in the outlying areas of San Francisco and Daly City. As shown in Table 8, the corridor population was 495,000 in 1975, a decline of 3% from 1970. The population is racially diverse; 45% is classified as nonwhite by the 1970 U.S. Census. Spanish-Americans make up the largest minority group; many of them live in the Mission District of San Francisco. Mean family income in 1969 ($11,700) was significantly lower than the average for the primary BART service area as a whole. The journey to work was made by automobile by only 53% of the population according to the 1970 Census, by far the lowest percentage of the five corridors.

Richmond BART Service Corridor. The Richmond BART corridor covers a 22 square mile area of fairly dense older urban development in Berkeley, El Cerrito, and Richmond. The corridor population was 220,000 in 1975, a decline of 9% from 1970. It includes a high percentage of minorities (35%), most of whom are black. The average family income level is rather lower than the overall primary service area average.

Concord BART Service Corridor. The Concord corridor covers an area of 110 square miles, much of it undeveloped or in new low-density residential development. The population was 234,000 in 1975. Of the five corridors included in Table 8, the Concord corridor had by far the highest rate of population growth from 1970 to 1975 (7%), and the highest mean family income in 1969 ($15,800), 28% higher than the mean for the primary service area as a whole. The population is nearly all white (93%) and relatively young. Transit use for the work journey was only 7% in 1970, but, as documented later in the report, BART has been particularly successful in attracting ridership in this corridor.

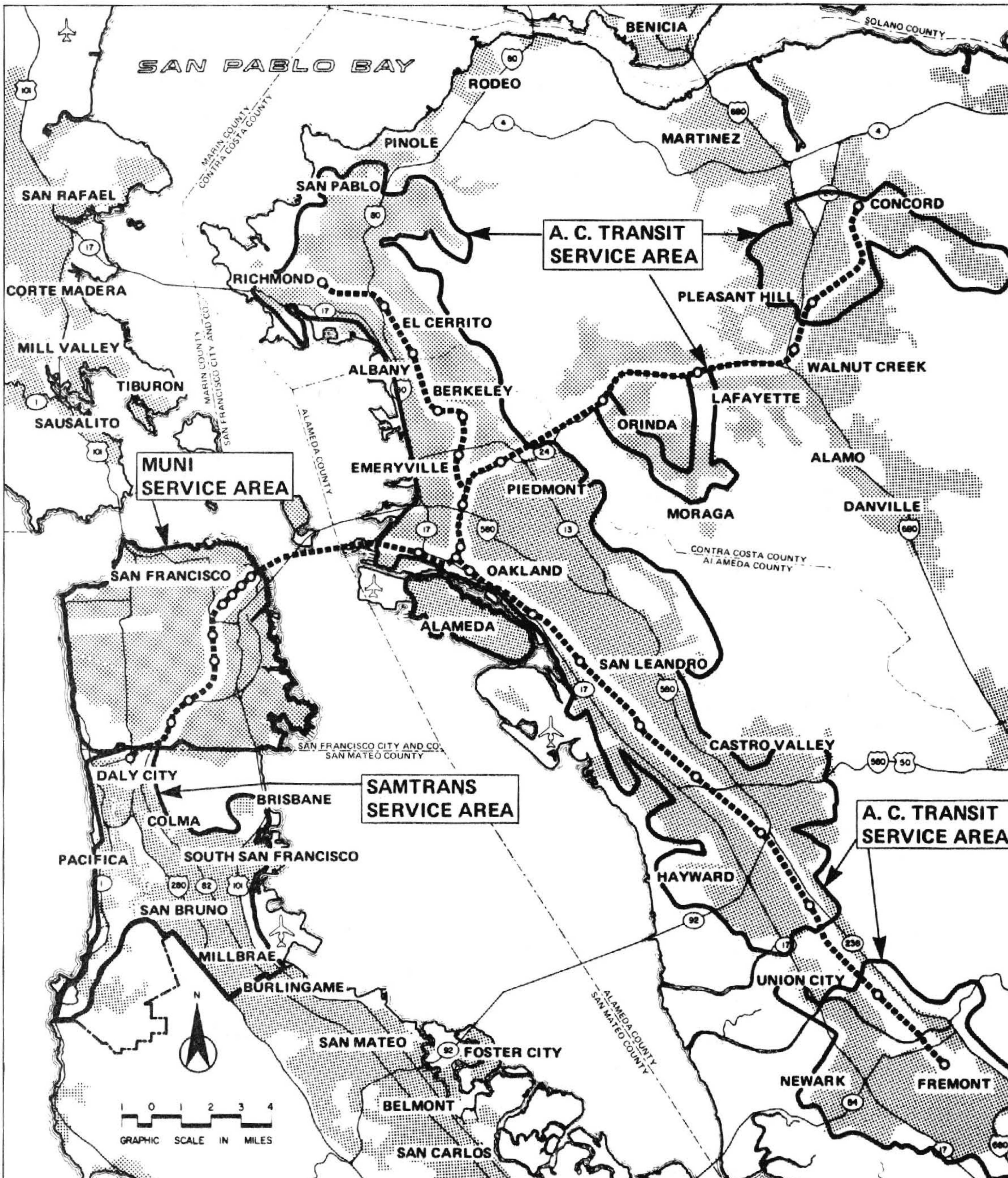
Fremont BART Service Corridor. The Fremont corridor covers an area of 136 square miles of diverse development, ranging from old inner-city areas of Oakland to newly developed and undeveloped areas around Fremont, Union City, and Hayward. The 1975 population was 499,000, an overall increase of 4% from 1970. Minorities, mostly Spanish-Americans, make up 35% of the population. Mean family income in 1969 was $11,400, the lowest of the five corridors; but only 8.1% of families lived below the poverty level according to the 1970 census, far fewer than for the Daly City or Oakland corridors.

Central Oakland BART Service Corridor. The Oakland corridor covers 18 square miles, much of it older, dense urban development. The 1975 population of 158,000 represents a 7% decline from 1970. The corridor has the highest percentage of minorities of the five corridors; 48% were defined as nonwhite in the 1970 census, and most of these were black. The population also has the highest percentages of elderly people and families below the poverty level. However, the mean family income is not much below the overall primary service area average.

Other Bay Area Transit

Alameda-Contra Costa Transit District (AC Transit). As shown in Figure 8, AC Transit provides bus services in most of the areas served by the three East Bay BART lines. AC Transit's service area covers over 200 square miles and has a population of over 1 million. Until recently, AC Transit served cities to the west of the Berkeley Hills only as far south as Hayward. However, since 1974, local service has been introduced in southern Alameda County and central Contra Costa County, as shown in the figure.

In addition to these East Bay bus services, AC Transit operates extensive bus routes from the East Bay across the San Francisco-Oakland Bay Bridge to the transbay bus terminal in downtown San Francisco. Under contract to the BART District, AC Transit also operates "BART Express Bus" service to and from those portions of the BART District counties beyond the immediate service area of BART stations. Service on five Express Bus



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

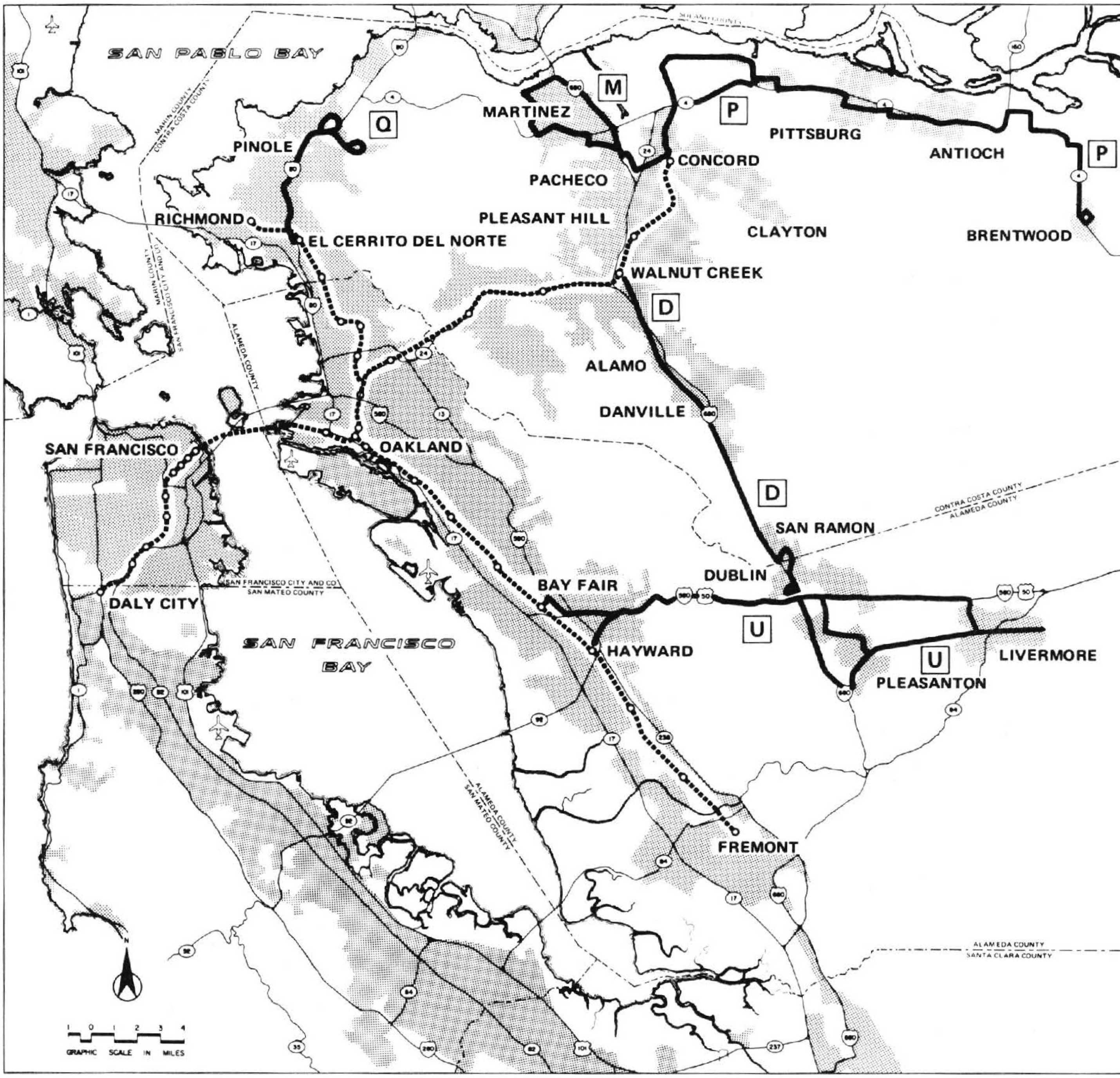
FIGURE 8

AC TRANSIT, MUNI, AND SAMTRANS SERVICE AREAS routes, as shown in Figure 9, began in late 1974. Including the Express Bus services, AC Transit buses connect with all 25 BART stations in the East Bay. At the end of fiscal year 1977, AC Transit had in service a fleet of 824 buses operating 201 lines with a total one-way route mileage of 2,214 miles. Over 30 million vehicle miles were operated during the year.

San Francisco Municipal Railway (MUNI). MUNI provides bus, trolley, streetcar, and cable car service to the entire City of San Francisco, an area of 47 square miles with a population of about 660,000. MUNI provides bus service to all nine stations on the Daly City BART Line, including the Daly City station itself, in San Mateo County. At the end of fiscal year 1977, MUNI operated a fleet of 1,000 vehicles, comprising 503 diesel buses, 343 electric trolley buses, 115 streetcars, and 39 cable cars. In fiscal year 1977, 26 million vehicle miles were operated on 80 lines over a one-way route mileage of 805 miles.

San Mateo County Transit District (SamTrans). The newly formed SamTrans system provides local bus services between the Daly City BART station and parts of San Mateo County, including Daly City, San Francisco International Airport, San Bruno, and South San Francisco. As shown in Figure 8, SamTrans provides local bus service to nearly all parts of the greater BART service area in San Mateo County. SamTrans also operates local bus services to areas of San Mateo County outside the BART service area, and express buses from points on the San Francisco Peninsula to downtown San Francisco (not shown in Figure 8). The express bus services replace and upgrade bus service previously provided by Greyhound.

Greyhound Bus Lines. Greyhound commute buses serve the area east of the Berkeley Hills in central Contra Costa County, which is also served by BART Concord Line stations. Greyhound commuter routes principally provide express service between stops in Orinda, Lafayette, Walnut Creek,



LEGEND

- BART Lines and Stations
- Major Highways and Freeways
- Urbanized Areas

FIGURE 9

BART EXPRESS BUS LINES

Concord, and downtown San Francisco. As discussed in Chapter VII, transbay BART service has greatly reduced Greyhound ridership, and only about 10 peak-period express buses are now operated daily in each direction. Greyhound has filed a request with the State of California Public Utilities Commission to discontinue service altogether.

Southern Pacific Railroad. Southern Pacific provides commuter rail service between San Francisco and cities on the San Francisco Peninsula in San Mateo County and Santa Clara County to the south. Weekday ridership on the line averages about 16,000 trips. The area served by Southern Pacific is only marginally served by BART.

Golden Gate Transit. Besides furnishing bus service within Marin County and Sonoma County (to the north of Marin), Golden Gate Transit's fleet of about 250 buses offers high-quality express bus service across the Golden Gate Bridge to downtown San Francisco from many communities in Marin and central Sonoma Counties. Golden Gate Transit also provides daily ferryboat service to the Ferry Building on the edge of downtown San Francisco from two terminals in Marin County.

Other Bus Services Connecting with BART. As described, AC Transit, MUNI, and SamTrans together operate most of the feeder bus service to BART stations. In addition, publicly or privately operated buses and minibuses serve several stations, including Walnut Creek, Fremont, Union City, Berkeley, and Richmond in the East Bay; and Daly City in the West Bay.

Transfer Procedures. Travelers using AC Transit or MUNI to connect with BART pay only half the normal round-trip bus fare, but different transfer procedures apply for the two systems. AC Transit passengers pay the regular bus fare for their trip to the BART station. On their return trip, they can obtain a free transfer ticket in the BART station for a bus ride to any destination within the same fare zone. MUNI passengers can purchase a two-part ticket for the price of one regular fare ($0.25) in BART stations. One part of the ticket is valid for the transfer from BART to MUNI, and the second part is valid for a return trip. The ticket bears the name of the BART station where it was issued and is valid for 3 days. At present, no discount transfer arrangements exist for operators other than AC Transit and MUNI.

The Highway System

Each of the BART lines more or less parallels a major freeway. The Daly City Line parallels I-280 and Route 101; the Richmond Line, I-80; the Concord Line, Route 24; and the Fremont Line, Route 17 (and to a lesser extent I-580). As shown in Figure 10, Oakland and the other East Bay cities are linked to the San Francisco Peninsula and Marin County by three major highway toll bridges: the San Francisco-Oakland Bay Bridge (generally known as the Bay Bridge), the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge.

The other major highway links highlighted in Figure 10 are the Golden Gate Bridge linking Marin County to San Francisco; and the Caldecott Tunnel on Route 24 through the Berkeley Hills linking central Costra Costa County to Berkeley, Oakland, and the Bay Bridge. Characteristics of these five key highway links are given in Table 6.

The most important of these highway links for this study is the San Francisco-Oakland Bay Bridge, which parallels the BART Transbay Tube and connects the freeways of the San Francisco Peninsula and the employment centers of San Francisco directly to Oakland and the major freeways leading to the industrial and residential areas of the East Bay. The four freeways radiating from the eastern terminus of the Bay Bridge (I-80, Route 24, I-580, and Route 17) have a total of 32 lanes in both directions where they begin.

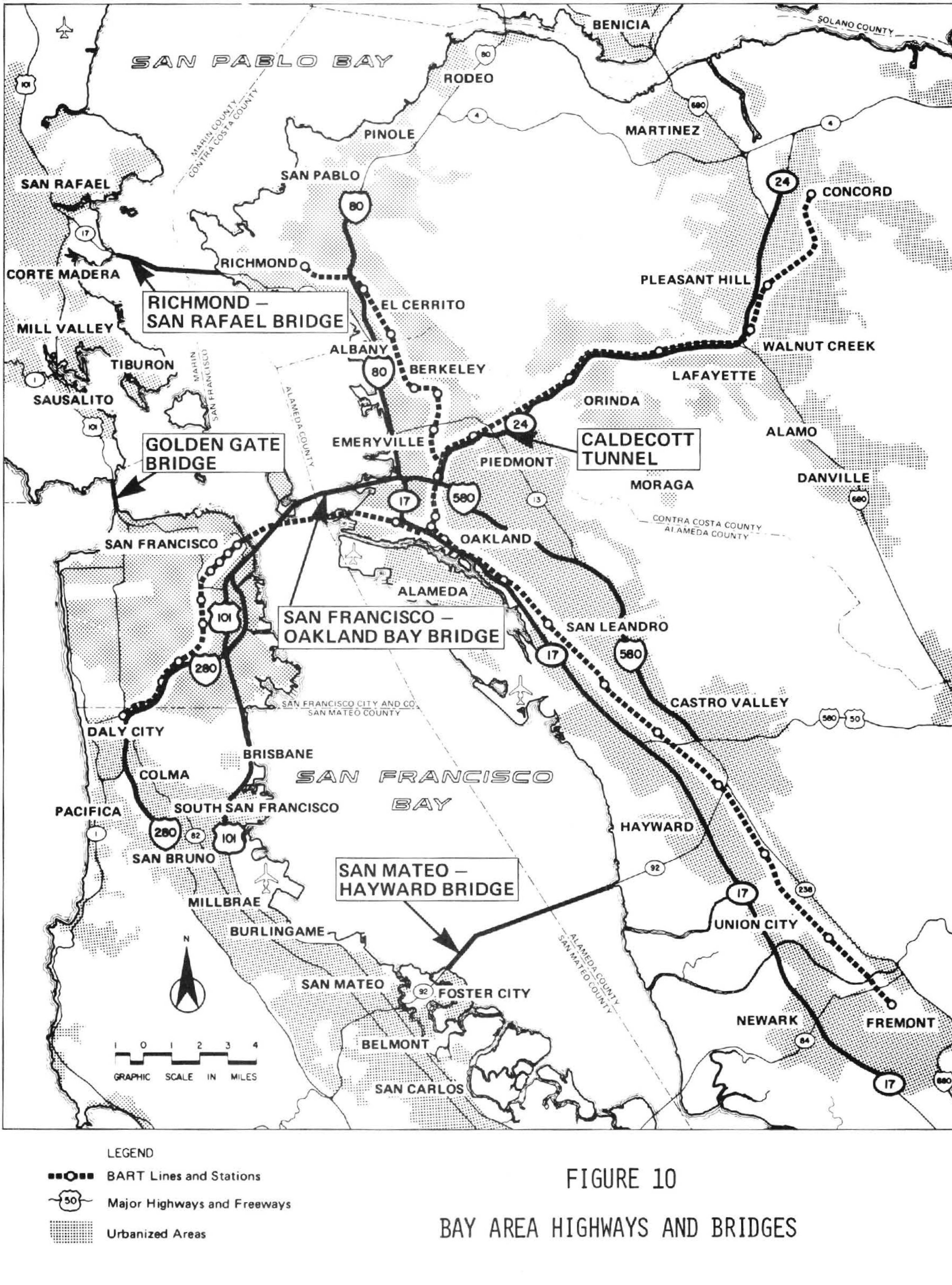


FIGURE 10

BAY AREA HIGHWAYS AND BRIDGES

Table 6

KEY BAY AREA HIGHWAY LINKS

Highway Link	Total Lanes in Both Directions	Total Toll Charge for Both Directions[a]	Average Daily Vehicles in Both Directions
San Francisco-Oakland Bay Bridge	10	$0.75/$0.60	190,000
San Mateo-Hayward Bridge	4 (6 at center span)	$0.75/$0.60	30,000
Richmond-San Rafael Bridge	6	$1.00/$0.60	20,000
Golden Gate Bridge	6	$1.00	100,000
Caldecott Tunnel	6	None	100,000

a. The first number is the normal toll for passenger cars; the second is the charge for prepaid commuter ticket books. Tolls are paid in the westbound (or southbound) direction only. On the Bay Bridge, San Mateo Bridge, and Golden Gate Bridge, cars containing three or more persons pay no toll at peak periods. (This has recently been extended from 6:00 a.m. to 6:00 p.m. on the Bay Bridge.) Tolls on the Bay Bridge and San Mateo Bridge were increased from $0.50 ($0.40 commute book) and from $0.70 ($0.40 commute book), respectively, effective July 1977. Tolls on the Golden Gate Bridge were increased from $0.50 to $0.75 effective March 1973, and from $0.75 to $1.00 effective November 1977.

Bay Area Travel Patterns

Origin-Destination Distribution. According to journey-to-work data from the 1970 U.S. Census, 876,000 workers travel daily from residences in the greater BART service area by automobile, truck, bus, streetcar, or commuter railroad. The downtown areas of Oakland and San Francisco, which are best served by BART, are the most concentrated employment destinations. The area defined by the census as the San Francisco central business district accounts for 194,000 trips, or 22% of all greater BART service area work trip destinations. However, most of these downtown trips are made from residence locations not easily accessible to BART. For example, two-thirds of trips to downtown San Francisco are from other parts of San Francisco, but most of these are from northern and western areas which BART does not serve effectively. Large numbers of trips are also made between outlying areas of Oakland and San Francisco and within suburban areas not served by BART. Thus, although BART provides service in some of the major commute corridors, including the San Francisco-Oakland Bay Bridge corridor, the number of trips that BART can be expected to serve, relative to all work trips made areawide, is small.

According to the 1970 census, a total of about 67,000 workers traveled daily via the San Francisco-Oakland Bay Bridge between residences in the East Bay and workplaces in San Francisco or on the San Francisco Peninsula. About 14,000 workers traveled daily in the opposite direction. The total number of work trips made in each direction across the Bay Bridge was thus about 81,000 throughout the day, compared with the total of 876,000 made areawide. In subsequent discussions of travel in the Bay Bridge corridor (where BART's impacts have probably been greater than anywhere else in the transportation system), it should be borne in mind that, although the Bay Bridge is an important commute corridor in the greater BART service area as a whole, it is used for less than 1 work trip in 10.

Trip Lengths. According to the 1970 U.S. Census journey-to-work survey, for work trips to and from residences throughout the greater BART service area, the average one-way trip was 9 miles long and took about 23 minutes. Work trips made by automobile were slightly shorter than the average (8.6 miles and 20 minutes travel time). Correspondingly, work trips by transit were slightly longer in distance but took much longer in time (10.2 miles and 34 minutes).

These areawide average trips are very much shorter than trips currently made by BART. The average journey to work by BART covers about 17 miles (13 miles on BART itself, and 4 miles to and from stations) and takes about 50 minutes door-to-door. Transbay BART trips are longer still, averaging about 23 miles (19 miles on BART and 4 miles to and from stations) and taking 60 minutes door-to-door.

Thus, as discussed more fully in Chapter VI, BART serves (and competes with the automobile for) long distance trips that make up a relatively small proportion of all areawide trips. This point is illustrated further by results from the work travel survey. Trips currently being made by automobile for which BART is considered the best alternative average 16 miles and take 29 minutes door-to-door. Transbay automobile work trips for which BART is considered the best alternative average 22 miles and take 35 minutes.

Table 7a

SOCIOECONOMIC CHARACTERISTICS OF GREATER BART SERVICE AREA

Socioeconomic Characteristic	County of Residence: Alameda	Contra Costa	San Francisco	Northern San Mateo[a]	Total BART Service Area
Sex					
Male	49.0%	49.2%	48.3%	49.3%	48.9%
Female	51.0	50.8	51.7	50.7	51.1
	100.0%	100.0%	100.0%	100.0%	100.0%
Age					
Under 16	27.8%	32.0%	19.7%	31.9%	26.8%
16 to 17	3.4	4.2	2.6	3.8	3.4
18 to 24	14.0	10.1	13.6	11.0	12.7
25 to 34	14.1	12.9	15.1	14.9	14.2
35 to 44	11.2	12.7	11.2	13.1	11.7
45 to 54	11.7	13.0	12.1	12.6	12.2
55 to 64	8.6	8.2	11.8	7.6	9.3
65 and over	9.2	6.9	13.9	5.1	9.7
	100.0%	100.0%	100.0%	100.0%	100.0%
Education Level (Population 25 years and older)					
Less than high school	37.0%	32.1%	38.2%	32.1%	36.0%
High school graduate	33.5	33.9	29.4	41.2	32.9
Some college	14.9	16.8	15.7	16.6	15.7
Four or more years of college	14.6	17.2	16.7	10.1	15.4
	100.0%	100.0%	100.0%	100.0%	100.0%
Annual Family Income--1975[b]					
Under $5,000	9.3%	7.0%	11.3%	5.0%	8.9%
$5,000 to $6,999	6.3	4.7	7.6	3.4	6.0
$7,000 to $9,999	9.3	7.4	11.1	6.5	9.1
$10,000 to $14,999	19.1	16.8	18.5	17.1	18.2
$15,000 to $24,999	35.9	38.2	31.0	43.7	35.9
$25,000 and over	20.1	25.9	20.5	24.3	21.9
	100.0%	100.0%	100.0%	100.0%	100.0%
Mean Family Income, 1969	$12,340	$13,778	$12,507	$13,446	$12,814
Number of Families, 1970	266,135	146,479	165,342	56,697	634,653
Percent of Families Below Poverty Level, 1970	8.1%	6.2%	9.9%	4.1%	7.8%
Ethnic/Racial Category					
White	67.2%	80.7%	57.2%	76.0%	68.1%
Black	15.0	7.4	13.4	2.4	11.8
Spanish-American[c]	12.6	9.3	14.2	16.5	12.7
Other	5.2	2.6	15.2	5.1	7.4
	100.0%	100.0%	100.0%	100.0%	100.0%
Total 1970 Population	1,073,184	558,389	715,674	217,980	2,565,227

a. Cities of Daly City, Colma, Brisbane, Pacifica, South San Francisco, San Bruno, and Millbrae.
b. 1969 census income distribution adjusted to reflect the change in the total U.S. income distribution from 1969 to 1975. (See Reference 11, Appendix C.)
c. This category comprises persons of Spanish tongue, all persons in families in which the head or wife reported Spanish as his or her mother tongue, and persons who have a Spanish surname.

Source: 1970 U.S. Census of Population and Housing.

Table 7b

SOCIOECONOMIC CHARACTERISTICS OF GREATER BART SERVICE AREA:
POPULATION AGED 16 YEARS AND OLDER

Socioeconomic Characteristic	County of Residence: Alameda	Contra Costa	San Francisco	Northern San Mateo[a]	Total BART Service Area
Sex					
Male	48.3%	48.5%	47.7%	48.7%	48.2%
Female	51.7	51.5	52.3	51.3	51.8
	100.0%	100.0%	100.0%	100.0%	100.0%
Age					
16 to 17	4.7%	6.1%	3.2%	5.5%	4.6%
18 to 24	19.3	14.9	16.9	16.2	17.4
25 to 34	19.5	19.0	18.8	21.8	19.4
35 to 44	15.5	18.6	13.9	19.3	16.0
45 to 54	16.2	19.2	15.1	18.5	16.6
55 to 64	12.0	12.0	14.7	11.2	12.7
65 and over	12.8	10.2	17.4	7.5	13.3
	100.0%	100.0%	100.0%	100.0%	100.0%
Ethnic/Racial Category					
White and other	75.1%	85.0%	76.6%	84.6%	78.3%
Black	13.6	6.7	11.1	1.9	10.5
Spanish-American[b]	11.3	8.3	12.3	13.5	11.2
	100.0%	100.0%	100.0%	100.0%	100.0%
1970 Population 16 years and older	774,734	379,792	574,150	148,396	1,877,072

a. Cities of Daly City, Colma, Brisbane, Pacifica, South San Francisco, San Bruno, and Millbrae.
b. This category comprises persons of Spanish tongue, all persons in families in which the head or wife reported Spanish as his or her mother tongue, and persons who have a Spanish surname.

Source: 1970 U.S. Census of Population and Housing.

Table 8

SOCIOECONOMIC CHARACTERISTICS OF PRIMARY BART SERVICE AREA[a]

	BART Service Corridors Comprising Primary BART Service Area					
	Daly City Corridor	Richmond Corridor	Concord Corridor	Fremont Corridor	Oakland Corridor	Total All Corridors
Number of Zones	53	16	17	32	14	132
Socioeconomic Characteristic						
Sex, 1975[b]						
Male	49.9%	48.5%	49.1%	48.7%	48.2%	49.1%
Female	50.1	51.5	50.9	51.3	51.8	50.9
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age, 1975[b]						
Under 16	21.6%	23.4%	32.1%	31.5%	19.8%	26.3%
16 to 17	2.6	2.9	4.5	3.9	2.7	3.3
18 to 24	13.2	18.8	9.4	12.0	14.6	13.2
25 to 34	15.4	15.1	12.5	13.3	13.3	14.1
35 to 44	11.8	9.3	13.8	11.7	9.7	11.5
45 to 54	12.1	11.2	13.3	12.0	12.0	12.1
55 to 64	10.9	9.2	7.4	7.9	11.9	9.3
Over 64	12.4	10.1	7.0	7.7	16.0	10.2
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Ethnic/Racial Category, 1975[b]						
White	55.2%	64.6%	92.5%	65.1%	52.0%	64.7%
Black	13.4	20.8	0.3	12.5	34.7	14.3
Spanish-American	17.5	7.8	5.7	18.3	6.0	13.6
Other	13.9	6.8	1.5	4.1	7.3	7.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Mean Family Income, 1969[c]	$11,677	$11,970	$15,794	$11,445	$12,107	$12,302
Number of Families, 1975[d]	106,681	47,970	61,098	127,763	36,722	380,234
Percent of Families Below Poverty Level, 1970	10.5%	8.8%	3.3%	8.1%	11.2%	8.4%
Number of Workers, 1970[e]	220,464	95,813	81,943	179,222	67,527	644,969
Work Trip Mode, 1970[f]						
Automobile	53.4%	72.5%	85.8%	85.7%	65.3%	70.6%
Transit	30.1	11.4	6.6	7.4	19.1	16.9
Other	16.5	16.1	7.6	6.9	15.6	12.5
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total Population, 1970	509,318	240,834	218,700	481,486	170,099	1,620,437
Total Population, 1975	494,805	219,542	233,975	499,254	158,090	1,605,666
Percent Change in Population, 1970 to 1975	-2.8%	-8.8%	7.0%	3.7%	-7.1%	-0.9%

a. See text for definition of areas.

b. Percentage distributions from the 1970 census were applied to 1975 population totals for each zone to estimate the number of people in each category in 1975. The percentages in the table are based on aggregates of the resulting 1975 estimates for each category.

c. Weighted average computed by weighting census tract averages by number of families in each census tract, 1970.

d. The number of families obtained from the 1970 census adjusted according to the percentage change in the total population from 1970 to 1975.

e. The number of workers in 1970 as obtained from the 1970 census and used as the base for work trip mode percentages (footnote f).

f. Automobile: driver or passenger in private automobile; transit: bus, streetcar, or train; other: walked to work, worked at home, or other mode.

Sources: U.S. Census of Population and Housing, census tract data for 1970.
Association of Bay Area Governments (ABAG) Provisional Series 3 Projections of population and employed residents for 1975 (March 1977).

DETERMINANTS AND NATURE OF

BART RIDERSHIP

IV. DETERMINANTS OF BART RIDERSHIP

The typical traveler bases his choice of travel mode on the service characteristics of the available alternatives (travel times, costs, transfers required, and other less easily quantified factors such as dependability and comfort), his perceptions of these characteristics, and the importance he attaches to each characteristic. In most trip mode choices, travel time is the single most important determinant.

This chapter compares the service characteristics of BART with those of the bus and private car, and analyzes the reasons for people's choices between BART and bus, or between BART and car, in terms of the relative levels of these service characteristics.

The first section of the chapter compares average zone-to-zone travel times for travel by the transit system (with and without BART) and by car, as estimated from network representations of the transportation system. Later sections analyze travelers' choices between BART and bus and BART and car in terms of both travel time and other service characteristics, as reported by respondents to the 1974 transbay travel survey and the 1977 work travel survey.

Network Travel Time Comparisons*

The zone-to-zone travel times analyzed in this section are derived from three network representations of the transportation system serving the 239-zone greater BART service area: the "with-BART", "no-BART", and "highway" networks. The analyses focus on (1) peak-period travel times from the set of 239 zones to a set of 50 zones representing the locations of major employment opportunities, and (2) off-peak travel times from the set of 239 zones to a set of 50 zones representing the locations of major shopping centers.

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*The analyses reported in this section are based on networks and zone-to-zone trip volume estimates developed by the Metropolitan Transportation Commission. The analyses are detailed and documented in Reference 7.

The With-BART Network. The with-BART network is a representation of the entire 1976 transit system including BART, its bus feeder services, and other bus and streetcar services in the area. Times derived from the network represent estimates for travel (including walking, waiting, and transferring) between zone centroids via minimum time paths. These paths do not necessarily include the use of BART, so times from this network are not necessarily estimated travel times using BART itself. Two versions of the with-BART network are analyzed, one representing morning peak-period transit services, and one representing off-peak services.

The No-BART Network. The no-BART network is a representation of the hypothetical transit system judged by the BART Impact Program's analyses to be the one most likely to have evolved by 1976 had the 1962 BART bond issue vote failed. The no-BART system is similar to the system of bus and streetcar services existing immediately before the start of BART, and so provides a lower level of service than the with-BART system, particularly in outlying areas. As in the with-BART network, travel times from the no-BART network represent estimates of the time it would take to travel between zone centroids using transit (bus or streetcar) including walking, waiting, and transfer times. Two versions of the no-BART network are analyzed, one representing morning peak-period transit services and one representing off-peak services.

The Highway Network. The highway network represents the 1976 system of streets and highways. Travel times from this network represent estimates of the travel time required to drive between zone centroid locations via the minimum time path in the morning peak period. No off-peak highway network travel times are analyzed here.

Top 50 Employment Zones. The 50 employment zones analyzed are those in the 239-zone greater BART service area with the highest 1975 total employment. The distribution of these 50 zones and their employment is shown relative to the 88 zones defining the work travel survey area and their employment in Table 9. As shown in the table, 34 of the top 50 employment zones are inside the 88-zone work travel survey area. The work travel survey covered only workplaces that, for the most part, are reasonably accessible from BART. Thus, the degree of commonality between the top 50 zones and the survey area zones illustrates the extent to which BART serves major employment centers in the greater BART service area, particularly in the San Francisco and Oakland central business districts. Of the 17 zones defining the San Francisco and Oakland central business districts in the work travel survey area, 16 are included in the top 50 employment zones.

Top 50 Shopping Zones. The 50 shopping center zones analyzed are those in the 239-zone greater BART service area with the highest 1975 employment in retail trade and retail services, and in professional and other services. Like the top 50 total employment zones, these shopping center zones are largely concentrated in the downtowns of San Francisco and Oakland.

Weighted Average Travel Times. The average travel time between the 239-zone set and the 50-zone set (either employment or shopping) is computed by weighting the travel time between each of the (239 x 50 = 11,950) pairs of zones by an estimate of the number of trips made between that zone pair. This gives an estimate of trip-minutes spent in travel between all zones in the two sets. The average travel time is then calculated by dividing the estimated total number of trip-minutes by the total number of zone pairs (11,950).*

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*The number of zones is actually slightly less than 11,950 because not all zone pairs are connected by transit service in the networks.

Table 9

DISTRIBUTION OF TOP 50 EMPLOYMENT ZONES
RELATIVE TO WORK TRAVEL SURVEY AREA

	Distribution of Top 50 Zone Employment			Distribution of Work Travel Survey Area Employment	
		Employment in Zones			
Inside Work Travel Survey Area	Number of Zones	Total	Percent	Number of Zones	Employment in Zones
San Francisco CBD	13	259,000	39%	14	265,000
San Francisco Other	3	25,000	4	21	85,000
Oakland CBD	3	48,000	7	3	48,000
Oakland Other	3	39,000	6	7	56,000
Richmond Line	3	36,000	5	11	61,000
Concord Line	2	29,000	4	12	53,000
Fremont Line	7	68,000	10	20	109,000
Total Inside Work Travel Survey Area	34	504,000	75%	88	677,000
Outside Work Travel Survey Area					
West Bay	7	75,000	11%		
East Bay	9	93,000	14		
Total Outside Work Travel Survey Area	16	168,000	25%		
Top 50 Employment Zones Total	50	672,000	100%		

Note: Zones are defined by the Metropolitan Transportation Commission (MTC) 440 regional traffic zone system.

Source: Zonal Employment estimates are from the Association of Bay Area Governments (ABAG), Provisional Series 3 Projections, March 1977.

The estimates of zone-to-zone trip volumes used as the weighting factors are estimated total 1975 person-trips by all modes. Estimates of home-based work trips are used as the weighting factors for the analyses of peak-period (travel to employment) travel times, and estimates of home-based shopping trips are used as the weighting factors for the analyses of off-peak (travel to shopping) travel times. The estimates were derived from 1965 origin-destination survey data, updated to correspond to 1975 zone population and employment estimates.

Table 10 summarizes the average times for travel between zones in the 239-zone greater BART service area and the top 50 employment or shopping zone areas.

Comparison of With-BART and No-BART Transit Travel Times.* As shown in Table 10, in the peak period, comparison of the with-BART and no-BART times shows a with-BART advantage of 5 minutes or 12%. This 12% difference is surprisingly high and probably overstates the extent to which BART has actually improved average transit travel times areawide.

Comparisons of the with-BART and no-BART times for trips between different groups of zones within the analysis area (not shown in Table 10) document that BART provides the greatest improvements in transit travel times for trips from outlying suburban areas to zones in central Berkeley, Oakland, and particularly San Francisco. BART provides smaller improvements relative to the no-BART bus system for shorter trips and for non-downtown travel. With-BART network times are lower than no-BART network times for trips from virtually all areas except those along the BART Richmond Line. The higher with-BART times from Richmond Line areas to the top 50 employment zones reflects the lack of direct BART service from the Richmond Line to San Francisco.

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*Scrutiny of travel times from the networks suggests that many of the times incorporated in the no-BART network are unrealistically high estimates of what travel times on the no-BART transit system would likely be in reality. This probable source of bias, and other cautions associated with the network travel time comparisons are spelled out in Reference 12.

Table 10

WITH-BART TRANSIT, NO-BART TRANSIT, AND HIGHWAY NETWORK TRAVEL TIMES

Travel to:	Travel from: All 239 Zones in Greater BART Service Area			
	Average Travel Times (Minutes)		Difference	
	No-BART Transit	With-BART Transit	Minutes	Percent
Top 50 Employment Zones (peak period)	45.6	40.2	5.4	11.9%
	No-BART Transit	With-BART Transit		
Top 50 Shopping Zones (off peak)	40.6	34.2	6.4	15.7%
	Highway	With-BART Transit		
Top 50 Employment Zones (peak period)	26.5	40.2	-13.7	-52.0%

Note: See text for explanation.

Source: Peat, Marwick, Mitchell & Co. analyses of Metropolitan Transportation Commission networks and zone-to-zone trip estimates.

Comparisons of the off-peak with-BART and no-BART times to the top 50 shopping zones show a generally similar pattern to the peak-period comparisons, with BART providing the greatest improvements in transit times for travel from the more distant areas. As summarized in Table 10, the with-BART network shows a greater travel time advantage over the no-BART network off-peak than it does in the peak period. This reflects the high frequency of midday service provided on BART.

Comparison of With-BART Transit and Highway Travel Times. The with-BART transit system is most competitive with the automobile for travel to central San Francisco, Oakland, and Berkeley, especially from the more distant suburban areas, which are BART's principal markets. However, peak-period travel times by automobile are still much less than times from the with-BART transit network in nearly all cases. For many zones, the with-BART transit times to the top 50 employment zones are twice as long as the equivalent travel times by car. As summarized in Table 10, the average time by car for travel from all parts of the greater BART service area to the top 50 employment zones is 14 minutes less than the average time on the with-BART transit system, a 52% difference.

Other Factors Influencing Mode Choices

Many characteristics of BART, bus, and car journeys besides travel time influence individual travelers' mode choice decisions. The analyses of the reasons underlying individuals' mode choices summarized in the following sections of the report focus on 14 attributes describing the service provided by BART and the alternative modes. These are as listed in Table 11. The 1974 transbay travel survey questionnaire obtained information on all 14 attributes; the 1977 work travel survey questionnaire contained only the 8 indicated in Table 11. (These 8 were selected as the most important travel choice factors based on the earlier transbay data analysis.)

Table 11

MODAL SERVICE ATTRIBUTES INFLUENCING TRAVELER CHOICES

		Attribute Description	Abbreviation
W	P	Total door-to-door travel time	Total time
W	P	Time spent walking during the trip	Walking time
		Time spent waiting for vehicles	Waiting time
W		Dependability of arriving on time	Dependability
W	P	Chance of getting a seat	Chance of seat
		Comfort and smoothness of ride	Comfort
	P	Safety from accident or injury	Safety
W	P	Security from crime and unpleasant behavior of other people	Security
		Feeling of privacy	Privacy
W	P	Ability to do what you want while traveling	Activity en route
W	P	Flexibility to travel when you want	Flexibility
		Ability to combine different purposes in a single trip	Multipurpose
W	P	Total cost of door-to-door trip	Total cost
	P	Ability to find a place to park	Parking space

W Indicates that the attribute was included in both the 1974 transbay travel survey and the 1977 work travel survey. Other attributes were included only in the transbay survey questionnaire.

P Indicates that the attribute was included in the attribute set suggested by a principal components analysis of correlations among the data, and was used to estimate the transbay mode choice models.

Source: BART Impact Program 1974 Transbay Travel Survey.
BART Impact Program 1977 Work Travel Survey.

Survey Questionnaire Data. The questionnaires obtained ratings for each of these attributes measured on a seven-point semantic differential scale (with seven indicating "very satisfied" and one indicating "very dissatisfied"). In addition, the questionnaires requested a ranking of the attributes (and any other attributes considered important by travelers in their mode choice decisions), listed in their order of importance. The questionnaires also obtained travelers' estimates of travel times (broken down by time spent walking, waiting, and traveling in-vehicle), the number of transfers required between vehicles, and travel costs for BART and their alternative mode (bus or automobile).

Explanatory Mode Choice Models. In addition to the attribute importance rankings obtained directly from the questionnaire responses, estimates of the relative importance of the various attributes in travelers' mode choices were obtained from the coefficients of mathematical mode choice models estimated by using the survey data.*

In the transbay travel survey analysis, the sample of people choosing between BART and bus includes all respondents who were surveyed riding the bus (no matter what their second choice method), and all BART riders

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*These mode choice models express the probability of an individual choosing BART over bus or BART over automobile as a function of relative satisfaction ratings for the modal attributes listed in Table 11. In estimating the models, the dependent variable is specified as a binary (1 or 0) variable depending on whether BART is the first or second choice mode, respectively. The explanatory variables are the differences in satisfaction ratings (BART minus second choice mode) for each of the 14 attributes (8 for the work travel survey analysis). The models employ a nonlinear functional form based on the logistic function and model coefficients are inferred using maximum-likelihood estimation procedures. Ratios of the inferred coefficients of the models can be interpreted as measures of the relative importance attached to the various attributes by travelers in choosing their modes. The assumptions and structure of the mode choice models are detailed in Reference 12, pp. 1-6. The remainder of that report describes the estimation of the models using the transbay travel survey data set.

whose usual mode was bus before BART started service. Similarly, the BART-automobile choice sample includes all respondents who were surveyed driving and those BART riders who gave driving as their previous travel mode. In the work travel survey, the BART-bus sample includes all people who gave BART as their first choice for travel to work and bus as their second choice, or vice versa. The BART-automobile choice sample is composed of all travelers having BART and "drive alone or with a family member" as their first and second choices.

The results of the explanatory mode choice models must be interpreted cautiously for several reasons. The models embody assumptions about people's travel behavior that are open to challenge. The limitations of the data set from which the model coefficients are estimated also have implications for the meaning of the results.

Perhaps the most important of these limitations is that, as with all statistical-inferential models, the procedures used to estimate the coefficients of the mode choice models depend on variation within the observed data. If little or no variation exists among the observations of individuals' satisfaction ratings for a particular attribute--if, for example, nearly all travelers rate their satisfaction with the safety of both BART and bus equally highly--then this attribute will not be indicated by the model as a significant factor in their choice. This will be the case even though safety may well be very important to them in an absolute sense or would be important if a choice were to be made between two modes, one of which was perceived as safe and one as unsafe. As a consequence, the estimates of relative importance produced by the models apply only to the circumstances of the specific travel choices for which the data were observed.

Nevertheless, the analyses of the attribute satisfaction ratings data show intuitively reasonable, internally consistent, and statistically significant results, and suggest that the coefficients of the mode choice models do form a reasonable basis for assessing the relative importance of modal attributes. Comparison of the estimates of attribute importance as inferred from the models, and corresponding estimates of attribute importance as reported directly in the survey questionnaires, also tends to support the model results.

Transbay Travel Mode Choices

This section summarizes results from analyses of travel mode choices based on data from the 1974 transbay travel survey.*

Correlations Among Mode Choice Factors. As is to be expected where satisfaction ratings are collected for as many as 14 different modal attributes, there are high correlations between the relative satisfaction ratings for many attribute pairs. These arise for two related reasons: (1) the words used to describe two different attributes may mean essentially the same thing to many people (as in the case of "privacy" and "security from crime and unpleasant behavior of other people," for example), and (2) different attributes are related by functional relationships ("time spent waiting" and "dependability of arriving on time," for example). Analysis of correlations among the transbay travel survey data confirms that people think in terms of fewer than 14 separate mode choice decision factors; 9 "principal components" account for nearly all the within-sample variance.

The transbay data show particularly high correlations among the relative satisfaction ratings for (1) total door-to-door travel time, (2) the time spent waiting for vehicles, and (3) dependability of arriving on time. That is to say, all three attributes appear to be closely identified with one another by people making mode choice decisions. All three

*Details and documentation of the transbay travel analyses and results summarized here are given in Reference 5, pp. 93-104, and Reference 12, pp. 13-40.

attributes are also intuitively important in travel mode choice, perhaps particularly (in the case of dependability) where BART is concerned, and can be expected to make separate contributions to people's mode choice decisions. Unfortunately, correlations among the data are so high that the three cannot be distinguished as separate statistically significant attributes in the explanatory mode choice models. This same problem arises with some of the other 14 attributes.

To avoid the statistical problems arising from these correlations, a subset of 9 attributes (representing the 9 principal components) was used to estimate the models instead of the entire 14, as shown in Table 11. Thus, 5 attributes are included in the analysis by proxy. The influence of the dependability and waiting time attributes, for example, are consequently not represented explicitly in the model results. Instead, their influence is reflected by the other attributes, with which they are highly correlated, in particular total time. Note that exclusion of the 5 attributes does not necessarily mean they are unimportant determinants of travel choice, but simply that the observed data do not permit their influences to be estimated separately.

Important Factors in Transbay Mode Choices. Reflecting the different choice situations faced by different traveler groups, the results of the model estimations show significant differences among the various sample stratifications analyzed, particularly between (1) travelers making BART-automobile choices and those making BART-bus choices and (2) travelers making work trip choices and those making nonwork trip choices.

Nevertheless, all four groups show basic similarities. In particular, for all four groups, total travel time (incorporating the effects of excluded attributes, such as dependability) appears as one of the top two most important attributes. The time spent walking is also explicitly an important determinant of mode choice for transbay work trip-makers. Qualitative aspects of service tend to be less important determinants of choice. These general conclusions are confirmed by the analyses of the work travel survey, which are documented in the following section.

Journey-to-Work Travel Mode Choices

This section summarizes results from analyses of travel mode choices based on data from the 1977 work travel survey.

Definition of Choice Samples. As estimated by the work travel survey, the total population of commuters choosing between BART and bus (as their first or second choice modes) is 31,800. Of these commuters, 54% choose BART over bus, and 46% choose bus over BART. Of the 91,100 commuters having BART and driving alone as their first or second choice modes, 27% choose BART over automobile and 73% choose automobile over BART. These four traveler groups (BART over bus, bus over BART, BART over automobile, automobile over BART) are analyzed in the following sections.

Choices Between BART and Bus. Tables 12, 13, and 14 summarize the analysis of data for the sample of travelers choosing between BART and bus for their journeys to work. Information is given separately for those who usually choose BART in preference to bus and those who usually choose bus in preference to BART. Within each of these two groups, information on trip characteristics is given for both the BART and bus alternatives.

Table 12 gives information on the usual average travel time and its components (getting from home to the bus or BART, riding in the vehicle, and getting from the vehicle to the workplace); the average day-to-day variation in total travel time; the number of transfers required during the trip, and the average fare. Table 13 summarizes travelers' satisfaction with both the quantitative (time and cost) service attributes

Table 12

ALTERNATIVE JOURNEY-TO-WORK CHARACTERISTICS:
TRAVELERS CHOOSING BETWEEN BART AND BUS[a]

	Travelers Choosing BART over Bus		Travelers Choosing Bus over BART	
	BART Trip	Bus Trip	BART Trip	Bus Trip
Traveler Population	17,300		14,500	
Usual Travel Time (minutes)				
To Mode	12	13	14	10
On Mode	26	32	28	26
From Mode	8	12	9	10
Total	46	57	51	46
Slowest Travel Time (minutes)	54	63	61	53
Fastest Travel Time (minutes)	36	44	40	39
Range (minutes)	18	19	21	14
Number of Vehicles Used	1.9	1.7	2.1	1.5
Round-trip Fare	$1.34	$0.93	$1.44	$0.97

a. Bus mode includes streetcar.

Source: BART Impact Program, 1977 Work Travel Survey.

Table 13

SATISFACTION WITH ALTERNATIVE MODE ATTRIBUTES:
TRAVELERS CHOOSING BETWEEN BART AND BUS[a]

	Average Satisfaction Ratings[b]					
	Travelers Choosing BART over Bus			Travelers Choosing Bus over BART		
Service Attribute	BART Trip	Bus Trip	Difference	BART Trip	Bus Trip	Difference
1. Total door-to-door trip cost	4.5	5.6	-1.1	3.6	5.9	-2.3
2. Time spent walking	5.8	5.4	0.4	5.3	6.0	-0.7
3. Dependability of arriving on time	4.3	4.1	0.2	3.1	5.5	-2.4
4. Chances of getting a seat	4.7	4.4	0.3	3.8	5.7	-1.9
5. Security from crime and unpleasant behavior	5.4	3.8	1.6	5.1	5.1	0.0
6. Ability to do what you want while traveling	5.3	4.2	1.1	4.9	5.4	-0.5
7. Flexibility to travel when you want to	4.6	4.0	0.6	4.2	4.7	-0.5
8. Total door-to-door travel time	4.6	3.4	1.2	3.4	5.3	-1.9

a. Bus mode includes streetcar.
b. Attribute satisfaction ratings obtained from 7-point semantic differential scales where very satisfied = 7, very dissatisfied = 1.

Source: BART Impact Program, 1977 Work Travel Survey.

and other less easily quantifiable attributes. Table 14 gives estimates of the importance attached to the various service factors by commuters choosing between BART and bus (1) as reported directly by questionnaire respondents and (2) as inferred from the coefficients of the mode choice models.

Table 12 shows that people choosing BART over bus report an average 11-minute one-way trip time advantage by BART (46 minutes by BART, 57 minutes by bus), but they pay much more for the trip than if they took the bus, and typically have to transfer between vehicles more often in their BART trip.

Satisfaction Ratings. Table 13 shows that those who have BART as their first choice give higher ratings to BART on all attributes than do those who have BART as their second choice. However, the satisfaction ratings given for BART, when compared relatively among the eight attributes, are very similar for both BART-over-bus and bus-over-BART groups. Thus, BART is consistently given high ratings on security and flexibility and low ratings on dependability and cost.

Similarly, for the bus ratings given in Table 13, satisfaction is higher for all attributes among those whose first choice mode is bus than among those whose first choice mode is BART. But in relative terms, the satisfaction with bus service attributes is similar for the two choice groups. Bus is consistently given high ratings on total cost and chance of seat and low ratings on security and flexibility.

Examination of the differences between the BART and bus ratings (BART-minus-bus) in Table 13 shows that BART has the greatest satisfaction rating advantage over bus for the attributes of security, ability to do what you want while traveling, flexibility, and total time. Bus shows the greatest satisfaction advantage over BART for the attributes of dependability, cost, chance of seat, and walking time. The satisfaction ratings of Table 13 correlate closely with the information on travel times and costs given in Table 12.

Importance Ratings. Table 14 shows clearly that the factors people say are important to them vary as a function of their first choice mode. For example, travel cost (for which both BART and bus users give higher satisfaction ratings for bus than they do for BART), is considered the most important of all factors by people choosing bus over BART but is mentioned by relatively few people choosing BART over bus. Similarly, dependability is given a high importance rating by people choosing bus over BART, but a much lower rating by people choosing BART over bus.

To some extent, these differences may reflect travelers' justifications of their own decisions. That is, people who choose BART over bus may be unwilling to admit that travel cost and dependability are important to them, given that they know (or judge) the bus to be less expensive and more reliable. However, the differences between the importance rankings for BART and bus choosers also reflect the different preferences of the two groups. People to whom cost is important are less likely to choose the more expensive BART alternative (other things being equal), and people to whom reliability is important are less likely to choose the less reliable BART alternative.

Although there are obvious differences between BART and bus users with regard to the importance ratings shown in Table 14, there are also significant commonalities among the set of factors rated as most important in travelers' decisions. Travel time, waiting time, inconvenience (which is probably closely linked with walking time), and unreliability together account for 73% of all responses shown in the table among people choosing BART over bus, the same four attributes account for 62% of all responses among people choosing bus over BART.

Table 14

IMPORTANCE OF FACTORS IN MODE CHOICES:
TRAVELERS CHOOSING BETWEEN BART AND BUS[a]

A. FACTORS DIRECTLY REPORTED AS IMPORTANT BY SURVEY RESPONDENTS

Factor[c]	Importance Rating[b]: Travelers Choosing BART over Bus	Travelers Choosing Bus over BART
Total travel costs	21	100
Total travel time	100	44
Time spent waiting and transferring	49	40
Convenience	59	67
Reliability and regularity	26	67
Crowding	17	26
Comfort	18	5
Safety and security	23	4
Flexibility and independence	6	1

a. Bus mode includes streetcar.
b. Importance ratings were derived by summing the number of times each factor was mentioned by respondents as being the first, second, third, or fourth most important reason for their travel choice, and then normalizing so the most frequently mentioned equals 100.
c. The survey questionnaire asked respondents to list the important reasons for their travel choice in their own words. Questionnaire responses were grouped by the factors listed. Other reasons mentioned by respondents which do not specify a service characteristic, such as "method difficult to arrange" or "prefer usual method," are excluded.

B. FACTORS INFERRED AS IMPORTANT BY EXPLANATORY MODE CHOICE MODEL

Factor[d]	Importance Estimate[e]
Total door-to-door travel time	100
Ability to do what you want while traveling	92
Time spent walking	88
Dependability of arriving on time	63

d. Factors are as defined in the survey questionnaire. See Table 11.
e. Importance estimates are ratios of coefficients from the mode choice model, scaled so that the most important factor equals 100.

Source: BART Impact Program, 1977 Work Travel Survey.

Comparison of the reported importance ratings (given in the top part of Table 14) with the inferred importance estimates (given in the bottom part) shows that, if it is assumed that "inconvenience" is closely identified with the time spent walking, the two sets of results are consistent in the conclusion that overall, travel time (particularly time spent walking to and from and waiting for the bus or BART) and the travel time-related attribute of dependability are overwhelmingly the most important considerations to people choosing between BART and bus for their work journeys.* Comfort and other qualitative differences between BART and bus (on which great emphasis was placed in the design of BART) are not indicated as nearly such important factors in travelers' mode choices.

Choices Between BART and Automobile. Tables 15, 16 and 17 present information corresponding to that given in Tables 12, 13 and 14, respectively, except for the sample of travelers choosing between BART and driving alone (or with a family member) rather than between BART and bus.**

As shown in Table 15, the average journey to work on BART takes much more time than the alternative trip by automobile, both among the group

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*The attribute of "ability to do what you want while traveling," which is inferred as important in the explanatory model results of Table 15, is mentioned by virtually no one in the directly reported importance ratings of the table. This discrepancy probably reflects the high correlations existing between the activity en route variable and others such as security (correlation coefficient 0.50) and chance of seat (correlation coefficient 0.54) which influence the explanatory model output.

**The sample used in estimating the explanatory model results given in the second part of Table 17 differs slightly from the sample analyzed in Tables 15, 16 and the first part of Table 17 in that the data used to estimate the mode choice model are not weighted to account for non-response bias. In addition, driving alone is defined to mean just that (people driving with family members are excluded). Certain respondents are also screened out of the mode choice model analysis on the grounds that they do not effectively have a choice: people who need a car for work, people who do not drive, and people who do not have an automobile available.

Table 15

ALTERNATIVE JOURNEY-TO-WORK CHARACTERISTICS:
TRAVELERS CHOOSING BETWEEN BART AND AUTOMOBILE[a]

	Travelers Choosing BART over Automobile		Travelers Choosing Automobile over BART	
	BART Trip	Auto Trip	BART Trip	Auto Trip
Traveler Population	24,900		66,300	
Usual Travel Time (minutes)				
To Mode	13	—	14	—
On Mode	30	—	29	—
From Mode	8	—	12	—
Total	52	34	55	27
Slowest Travel Time (minutes)	62	48	63	39
Fastest Travel Time (minutes)	41	27	43	22
Range (minutes)	21	21	20	17
Number of Vehicles Used	2.0	1.0	2.3	1.0
Round-trip Fare	$1.62	$ —	$1.58	$ —
Parking and Bridge Tolls	$ —	$2.55	$ —	$1.83

a. Automobile defined as driving alone (or with a family member) by automobile, truck, or motorcycle.

Source: BART Impact Program, 1977 Work Travel Survey.

who usually drive and among those who usually take BART. In the case of people who usually drive, the alternative trip would take twice as long by BART (27 minutes driving, 55 minutes by BART). In the case of people who usually take BART, their trip is 18 minutes longer than their alternative automobile trip (52 minutes by BART, 34 minutes driving). However, this longer trip time is offset by the much lower trip cost by BART. Average BART trip fares are considerably less than average parking and bridge toll costs alone (without any allowance for gasoline and other running costs).

Satisfaction Ratings. As shown in Table 16, people who choose BART over the automobile rate their satisfaction with BART's attributes consistently higher than do those who choose the automobile over BART. Similarly, those who choose the automobile rate their satisfaction with the automobile consistently higher than those who choose BART. But, discounting this overall shift in the satisfaction ratings, the rankings of satisfaction with the various attributes (within a given column of the table) are almost identical for either BART or the automobile, no matter which is specified as the first choice mode.

Satisfaction ratings for BART are high for walking time, security, and ability to do what you want while traveling, and low for dependability and total time. The automobile is rated highest on flexibility to travel when you want to and walking time. The relative (BART-minus-automobile) satisfaction ratings show that the automobile is regarded more favorably than BART on all eight attributes among people who choose the automobile, and on all but two attributes (cost and ability to do what you want while traveling) even among people who choose BART. (This is in contrast to the BART-bus analysis of Table 13 where, among people who choose BART, BART is rated higher than the bus for seven out of eight attributes.) Satisfaction with BART is highest (relative to the automobile) for the ability to do what you want while traveling and cost, and lowest for dependability and total time.

Table 16

SATISFACTION WITH ALTERNATIVE MODE ATTRIBUTES: TRAVELERS CHOOSING BETWEEN BART AND AUTOMOBILE[a]

Service Attribute	Average Satisfaction Ratings[b]: Travelers Choosing BART over Automobile: BART Trip	Auto Trip	Difference	Travelers Choosing Automobile over BART: BART Trip	Auto Trip	Difference
1. Total door-to-door trip cost	4.6	3.8	0.8	4.1	5.3	-1.2
2. Total door-to-door travel time	4.4	5.7	-1.3	3.1	6.1	-3.0
3. Time spent walking	6.0	6.1	-0.1	4.9	6.5	-1.6
4. Dependability of arriving on time	4.0	5.8	-1.8	3.3	6.3	-3.0
5. Chances of getting a seat	4.8	7.0[c]	-2.2	4.3	7.0[c]	-2.7
6. Security from crime and unpleasant behavior	5.5	6.1	-0.6	4.8	6.4	-1.6
7. Ability to do what you want while traveling	5.4	5.1	0.4	4.8	5.8	-1.0
8. Flexibility to travel when you want to	4.6	6.2	-1.6	3.6	6.6	-3.0

a. Automobile defined as driving alone (or with a family member) by automobile, truck, or motorcycle.
b. Attribute satisfaction ratings obtained from 7-point semantic differential scale where very satisfied = 7, very dissatisfied = 1.
c. Assumed value (chance of seat attribute not included in questionnaire for auto).

Source: BART Impact Program, 1977 Work Travel Survey.

Importance Ratings. As in the BART-bus analysis, Table 17 reveals noticeable differences in the mode choice factors reported as important, depending on whether BART or the automobile is the first choice mode. Among people who choose BART over driving, cost and a dislike for driving in congested traffic are listed most frequently as important factors. (This is consistent with the observation in the previous paragraph that, among people who choose BART over driving, BART is rated higher than the automobile on only two attributes, cost and the ability to do what you want while traveling.) Reliability is mentioned as important by a trivial number of people choosing BART over driving. In contrast, reliability is one of the top three most important attributes listed by people choosing driving over BART.

In addition, there is an obvious difference in the importance attached to travel time and time-related attributes by the different groups. Among people who choose BART over driving, the travel time, waiting time, inconvenience, and unreliability factors together account for only 13% of the responses given in Table 17. In contrast, among people who choose driving over BART the figure is 63%. Apparently people who elect to ride BART accept that it takes longer and is less reliable than driving, but feel that these disadvantages are outweighed by the advantages of BART. These advantages are primarily BART's lower cost and the opportunity it affords to commuters to avoid driving in congested traffic and so make better use of their time while traveling. As with the BART-bus choice sample, the "qualitative" attributes of safety, security, comfort, and crowding are reported by very few people as important in their choices between BART and the automobile.

These findings tend to be supported by the results of the explanatory modeling analysis, given in the bottom part of Table 17. Travel time and walking time are indicated as the most important factors in peoples' choices between BART and driving. Again, it is reasonable to assume that the "inconvenience" quoted by many respondents, although not precisely defined, correlates with the time they must spend walking and waiting.

Table 17

IMPORTANCE OF FACTORS IN MODE CHOICES:
TRAVELERS CHOOSING BETWEEN BART AND AUTOMOBILE[a]

A. FACTORS DIRECTLY REPORTED AS IMPORTANT BY SURVEY RESPONDENTS

	Importance Rating[b]	
Factor[c]	Travelers Choosing BART Over Automobile	Travelers Choosing Automobile Over BART
Total travel cost	100	63
Total travel time	12	92
Time spent waiting and transferring	2	51
Convenience	12	100
Reliability and regularity	4	73
Crowding	--	19
Comfort	3	3
Safety and security	7	17
Flexibility or independence	1	22
Ability to make use of travel time	11	1
Dislike of driving in traffic	52	--
Parking unavailable or difficult	16	16
Car needed at work	--	42
Inconvenience to family members	9	5

a. Automobile defined as driving alone (or with a family member) by automobile, truck, or motorcycle.

b. Importance ratings were derived by summing the number of times each factor was mentioned by respondents as being the first, second, third, or fourth most important reason for their travel choice, and then normalizing so the most frequently mentioned equals 100.

c. The survey questionnaire asked respondents to list the important reasons for their travel choice in their own words. Questionnaire responses were grouped by the factors listed. Other reasons mentioned by respondents which do not specify a service characteristic, such as "method difficult to arrange" or "prefer usual method," are excluded.

B. FACTORS INFERRED AS IMPORTANT FROM EXPLANATORY MODE CHOICE MODEL

Factor[d]	Importance Estimate[e]
Total door-to-door trip cost	100
Time spent walking	83
Total door-to-door travel time	82
Security from crime and unpleasant behavior	52
Ability to do what you want while traveling	26

d. Factors are so defined in the survey questionnaire. See Table 11.

e. Importance estimates are ratios of coefficients from the mode choice model, scaled so that the most important factor equals 100.

Source: BART Impact Program, 1977 Work Travel Survey.

In addition, the lower cost of BART and the opportunity to avoid the aggravations of driving in peak period traffic are suggested as important factors in persuading people to use BART instead of driving to work.

Conclusions

The analysis of network travel times given in the first part of the chapter suggests that BART provides the most significant travel time improvements for long-distance, downtown-oriented trips by public transit, especially from outlying areas that would probably have relatively poor transit service without BART. These are the trips the system was primarily designed to serve. Smaller transit travel time improvements are provided for short-distance and non-downtown travel, largely because within-city and inner-suburban trips were already relatively well served by bus transit before BART. These trips within the central areas were never intended to be a primary focus of BART's service.

Analysis of transit travel time improvements for different socioeconomic stratifications of the population shows consistent results. Generally, BART provides smaller average transit travel time improvements for low-income, racial minority, elderly, and other transit-dependent population subgroups than for the population as a whole. Again, in large part, the reason is that many people in these disadvantaged groups live in central areas where typically much better bus service was provided before BART than it was in the more remote (and more affluent) suburbs.

BART provides significant improvements in transit travel times for many trips. However, for most trips, door-to-door trip times by BART are still much longer than times for the same door-to-door trips by automobile, even at periods of peak highway congestion. This is true for virtually all zone-to-zone trip movements, including those in the corridors best served by BART and the long-distance trips the System was originally designed to serve. Thus, with few exceptions, BART has not provided journey times competitive with the automobile, contrary to the hopes of many of the System's proponents and planners.

In addition to relative travel times, many service characteristics of the available modes influence travelers' decisions between BART and bus or automobile. Perceptions of BART's current service vary among travelers and with the circumstances of their mode choices, but show a fairly consistent overall pattern. Travelers generally perceive BART favorably with regard to its "qualitative" attributes: the comfort of the ride, safety from accident, security from crime, and, among those travelers choosing between automobile and BART, the opportunity it provides them to devote their attention to something other than driving in traffic. Travelers are generally much less satisfied with the "quantitative" aspects of BART service: the time they must spend waiting for trains, total journey times, reliability of service, and, among those who make a choice between BART and bus, the cost of the journey.

The importance travelers attach to the various service attributes in their mode choice decisions varies among individuals, but generally speaking, the important determinants of choice are the time spent traveling and the other quantitative service attributes. Comfort and the other qualitative aspects of service do not appear to be important considerations in most people's current choices between BART and bus or BART and car.

However, the list of factors reported by travelers as being the important determinants of choice varies significantly among individuals and as a function of the mode choice made. Among people choosing to take the bus to work rather than ride BART, the lower cost of the bus and its more dependable service are reported as important considerations, along with the total travel time required and "inconvenience" of the trip. The term "inconvenience" is used by travelers to mean different things, but to most people the time and trouble involved in having to transfer between transit vehicles (either bus or BART) are important aspects of the factor. This is evidenced by the much lower BART ridership on the Richmond-Daly City route, where a transfer between trains is currently required, than on the direct Concord-Daly City and Fremont-Daly City routes.

Among people who choose to drive to work rather than ride BART, the inconvenience associated with having to get to the BART station and wait for trains, and the unreliability of BART service, are typically reported as the important factors, along with total trip travel time. Difficulties in finding parking space at some BART stations contributes to the inconvenience of using BART and is an important determinant in some people's decisions to drive instead. The factor does not appear to be a critical constraint on overall BART ridership currently, but its importance will undoubtedly increase as demand increases.

People's decisions to ride BART rather than the bus to work are largely determined by the travel time savings possible on BART. These savings outweigh the typically higher cost of the BART journey (relative to the bus). People who elect to ride BART to work rather than drive generally accept that it takes longer and is less convenient and reliable than driving their own cars, but think that these disadvantages are outweighed by BART's advantages--primarily its lower cost (relative to the cost of driving and parking the car), and the opportunity it provides them to avoid the aggravations of driving in congested traffic and finding parking at their destinations.

V. BART RIDERSHIP CHARACTERISTICS

Average daily BART ridership since the start of transbay service in September 1974 is shown in Figure 11. Average weekday passenger trips are broken down by (1) trips made between stations on opposite sides of San Francisco Bay, (2) trips made between the 9 stations in the West Bay, and (3) trips made between the 25 stations in the East Bay. The System currently carries approximately 140,000 passenger trips per weekday: 60,000 transbay trips (40%), 40,000 (30%) within the West Bay, and 40,000 (30%) within the East Bay.

This chapter presents an analysis of historical BART ridership, origin-destination trip patterns, BART trip characteristics, and socioeconomic characteristics of BART tripmakers.

Historical BART Ridership

In total, weekday BART ridership appears to have grown at an average rate of about 5% per year over the 1-1/2 years since the last station of the System, Embarcadero, opened in May 1976 (although this growth rate is difficult to estimate confidently, given the disrupting effects of a recent BART strike which greatly reduced service, and an AC Transit strike which completely shut down the bus system). As shown in Figure 11, most of the recent increase in ridership has occurred in transbay trips. This reflects BART's relative service advantages for the long-distance transbay journeys which must otherwise be made on one of the two increasingly congested toll bridges across the Bay. Average daily West Bay ridership has not changed much over the months since the Embarcadero Station opened, and East Bay ridership has remained fairly constant over the entire 3-year period shown in the figure.

Future increases in average daily BART ridership can be expected as reliability improves, direct Richmond-Daly City service begins, and headways are reduced. However, likely near-term ridership increases

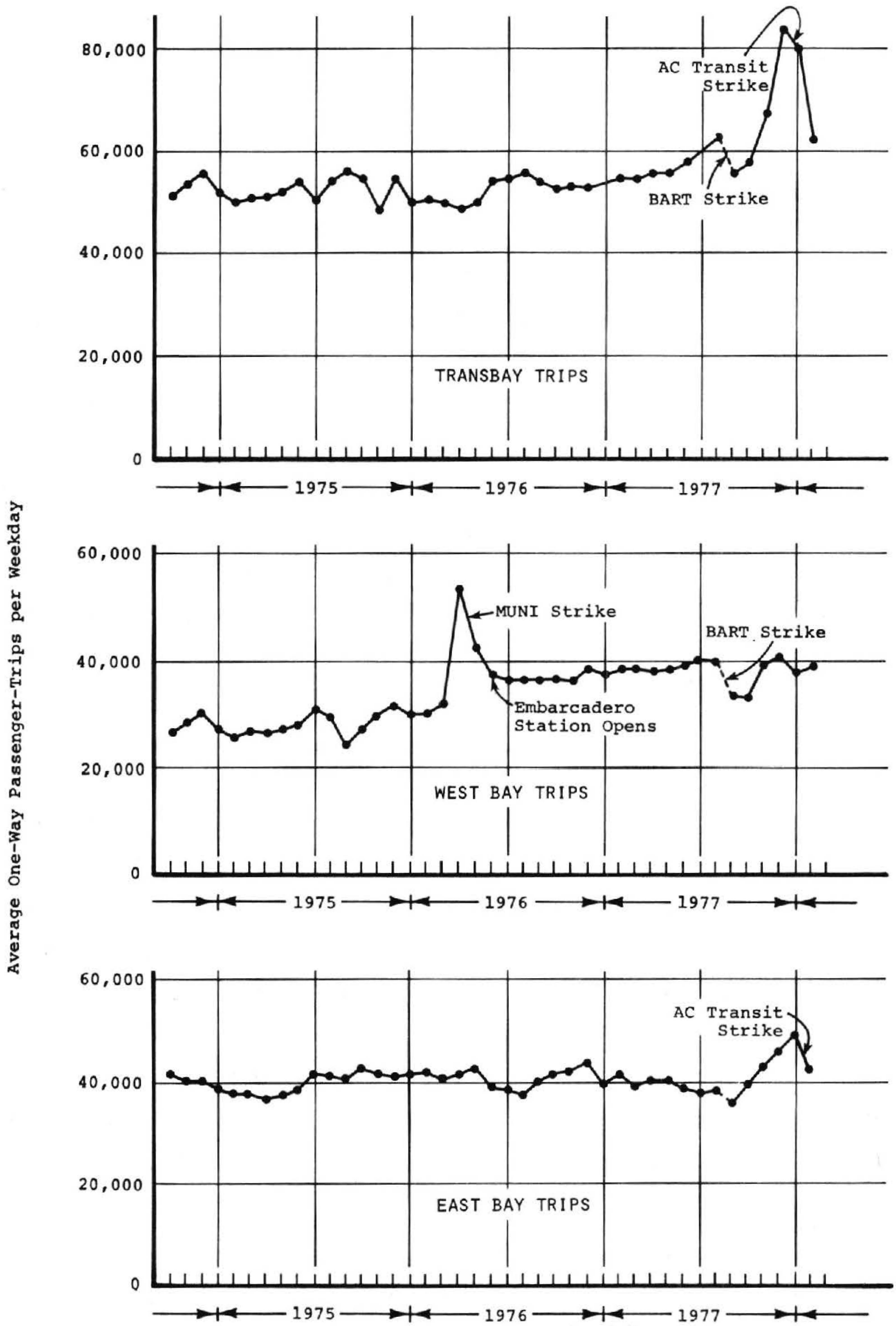

FIGURE 11

WEEKDAY BART RIDERSHIP, OCTOBER 1974-FEBRUARY 1978

Source: BART District Office of Research, Monthly Patronage Reports.

(although they may be significant) will probably not change the basic nature of BART's impacts discussed in later chapters.

The 1962 Composite Report predicted that average daily BART ridership in 1975, when full service was to be provided on all lines, would average 259,000 passenger trips per day (Reference 20, p. 81). A 1967 report, Coordinated Transit for the San Francisco Bay Area, predicted 253,000 average daily trips (Reference 21, p. 9). Following the start of BART service, the BART District revised the long-term full service ridership estimate downwards to 200,000 trips per day. Recent BART District projections are for an average daily ridership of between 170,000 and 180,000 trips per day by 1981 (testimony of BART District General Manager to State of California Assembly Committee on Transportation, December 1976). Thus, BART's current average daily ridership of 140,000 trips per day represents just over half the 259,000 ridership originally forecast for full service levels and about 80% of the BART District's near-term forecast.

Origin-Destination Trip Patterns*

The orientation of BART travel is predominantly to and from the downtown San Francisco and Oakland stations, especially during the peak periods when most BART trips occur. This is illustrated by the data in Table 18 which shows BART ridership station-by-station in the peak and off-peak periods. Stations are listed in order of total all-day ridership.
A total of 19,600 riders exit from the four downtown San Francisco stations (Embarcadero, Montgomery Street, Powell Street, and Civic Center) during the 2 hours from 7:00 a.m. to 9:00 a.m. These represent 60% of all riders exiting the System from 7:00 a.m. to 9:00 a.m.

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*Estimates of trip volumes given in this section are for October 1976. No major changes in the patterns have occurred to this time. A more detailed discussion of origin-destination and time-of-day trip patterns is given in Reference 10, pp. 15-32.

Table 18

BART RIDERSHIP BY STATION AND TIME OF DAY

Station	Time Period: Morning Peak 2 hours Number	Percent	Off Peak 13 hours Number	Percent	Evening Peak 3 hours Number	Percent	All Day 18 hours Number	Percent
Montgomery Street	9,307	58%	5,857	37%	857	5%	16,021	100%
Embarcadero	5,300	59	3,208	35	547	6	9,055	100
Powell Street	2,187	26	5,055	60	1,211	14	8,453	100
Daly City	259	3	2,343	32	4,856	65	7,458	100
Civic Center	2,773	39	3,439	49	877	12	7,089	100
19th Street Oakland	2,838	48	2,289	38	803	14	5,930	100
Berkeley	1,638	28	3,211	55	1,009	17	5,858	100
12th Street Oakland	1,797	34	2,638	50	835	16	5,270	100
Concord	153	3	1,463	34	2,793	63	4,409	100
Balboa Park	570	14	1,553	38	1,969	48	4,092	100
Walnut Creek	200	5	1,342	37	2,139	58	3,681	100
Fremont	193	5	1,518	42	1,911	53	3,622	100
Glen Park	93	3	1,121	31	2,353	66	3,567	100
Hayward	581	17	1,656	47	1,255	36	3,492	100
Pleasant Hill	152	5	970	28	2,243	67	3,365	100
24th Street Mission	225	7	1,282	43	1,507	50	3,014	100
Fruitvale	329	11	1,348	47	1,228	42	2,905	100
Lake Merritt	759	28	1,361	49	624	23	2,744	100
Bay Fair	160	6	1,034	38	1,543	56	2,737	100
Union City	113	5	846	35	1,421	60	2,380	100
San Leandro	294	13	1,032	45	952	42	2,278	100
Lafayette	117	5	676	32	1,354	63	2,147	100
Rockridge	300	14	1,008	48	802	38	2,110	100
16th Street Mission	371	18	952	45	766	37	2,089	100
MacArthur	318	16	961	47	755	37	2,034	100
Coliseum	328	17	1,054	53	596	30	1,978	100
El Cerrito del Norte	81	4	827	44	991	52	1,899	100
Orinda	180	10	627	34	1,045	56	1,852	100
South Hayward	149	9	518	32	949	59	1,616	100
Oakland West	179	11	609	39	799	50	1,587	100
Richmond	349	23	680	45	479	32	1,508	100
El Cerrito Plaza	113	8	663	44	705	48	1,481	100
North Berkeley	121	11	508	45	486	44	1,115	100
Ashby	91	8	587	55	396	37	1,074	100
Total	32,618	25%	54,236	42%	43,056	33%	129,910	100%

Note: Time periods are defined by time of exit, as follows:
Morning Peak: 7:00 a.m. - 9:00 a.m.
Off Peak: 6:00 a.m. - 7:00 a.m., 9:00 a.m. - 4:00 p.m.; 7:00 p.m. - 12 midnight
Evening Peak: 4:00 p.m. - 7:00 p.m.
Station locations are shown in Figure 1, Chapter II.

Source: BART Data Acquisition System, Summary of Faregate Counts, October 21, 1976.

A further 4,600 riders (14%) exit from the two downtown Oakland stations (19th Street and 12th Street) and another 1,600 (5%) exit from the Berkeley Station. These seven downtown stations rank among the eight busiest stations in the System.

A high proportion of these downtown trips is made from stations on the Concord Line and from the three outlying San Francisco stations. The busiest stations at the home end of the commute trip (as evidenced in Table 18 by a high number of riders exiting during the evening peak period) are Daly City, Balboa Park, and Glen Park on the Daly City Line; Concord, Walnut Creek, and Pleasant Hill on the Concord Line; and Fremont. These seven stations account for 42% of all exits during the period 4:00 p.m. to 7:00 p.m.

Analysis of the flows on the links between adjacent BART stations also shows the predominantly downtown orientation of BART travel and illustrates the imbalance between flows in opposite directions on most links of the System at the peak periods. For example, passenger trips through the Transbay Tube (westbound) to San Francisco in the morning peak (7:00 a.m. to 9:00 a.m.) typically total 11,600 trips, but only 1,500 trips are made through the Tube in the opposite (eastbound) direction during the same period. This is a 89%/11% split. On the link between Orinda and Rockridge (paralleling the Caldecott Tunnel) during the morning peak, 7,900 trips flow in the peak direction, compared with 600 trips in the reverse direction (a 93%/7% split).

The most heavily traveled links of the System are the transbay link between Oakland West and Embarcadero stations (53,000 trips daily in October 1976, and about 60,000 currently), and the link between 12th and 19th Street stations in Oakland which carries both Richmond and Concord Line riders (47,000 trips daily).

The way in which ridership is concentrated in the peak periods at most stations is shown in Table 18. Predominantly residential stations show a high percentage of exits in the afternoon peak, and predominantly workplace stations show a high percentage of exits in the morning peak. Of the total of 130,000 BART passengers who made trips during the entire operating day (6:00 a.m. to 12 midnight) in October 1976, about 32,600 (25%) exited the System during the 2 hours from 7:00 a.m. to 9:00 a.m. and 43,100 (33%) exited during the 3 hours from 4:00 p.m. to 7:00 p.m. The heavily peaked nature of BART ridership to the downtown areas is further illustrated in Figure 12 which shows the combined number of passengers exiting from the Embarcadero, Montgomery Street, Powell Street, and Civic Center BART stations during each hour from 6:00 a.m. through 12 midnight for a typical midweek day in October 1976.

Among stations showing a high percentage of passenger trips occurring in the off-peak period are Powell Street in San Francisco, which serves the downtown shopping district, and Berkeley, where a high percentage of trips are to and from the University of California.

BART Trip Characteristics*

This section summarizes the purposes, travel times, access modes, and other characteristics of BART trips. Data are from the 1976 BART passenger profile survey and are summarized in Tables 19 through 24 grouped at the end of the chapter. Tables 19 and 20 show distributions estimated for the entire 6:00 a.m. to midnight BART service day (representing 124,500 daily trips using the System at the time of the survey). Tables 21, 22, and 23 show the distributions as computed from data for

*A more detailed description of BART trip characteristics, including a breakdown by station, is given in Reference 11, pp. 31-44.

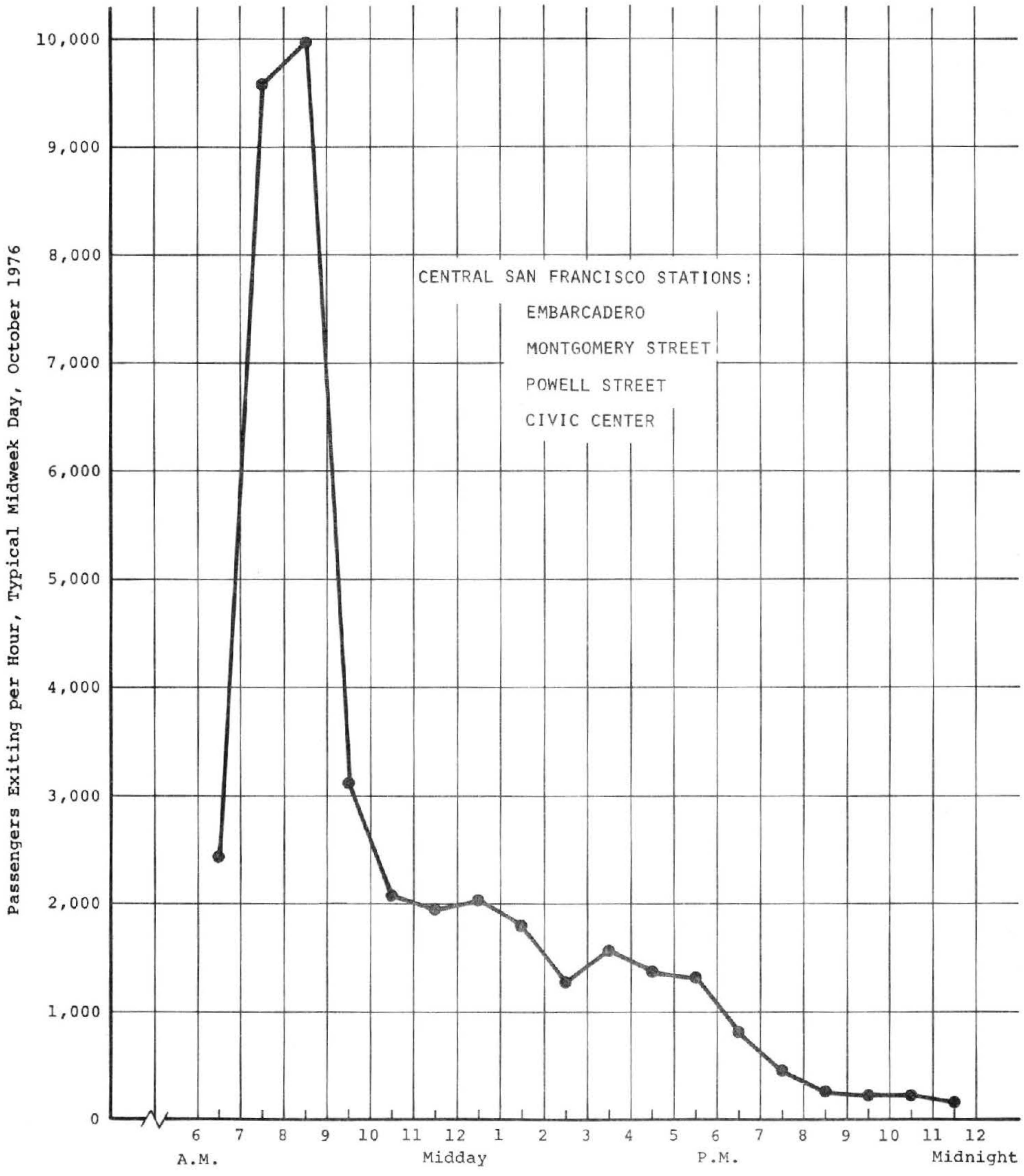

FIGURE 12

TIME-OF-DAY DISTRIBUTION OF BART RIDERS EXITING CENTRAL SAN FRANCISCO STATIONS

Source: BART District, Data Acquisition System Summary of Faregate Counts.

the 6:00 a.m. to 3:00 p.m. period of the survey (representing 66,800 trips).* In the discussions given in this and the following sections, all differences commented on are statistically significant at the 95% confidence level unless otherwise stated.

Table 19 shows distributions of BART trip characteristics by peak and off-peak periods. The distributions given in column 5 of the table show that BART travel is predominantly to and from work (67% of all trips). Trips to and from school make up the next largest single purpose (11%). The average BART trip takes 46 minutes door-to-door, of which 33 minutes are spent actually waiting for or riding on the train. A majority (61%) of BART trips are made by people who travel 5 days a week. Among peak-period travelers, the share is 76%; the remaining 24% use BART on 4 or fewer days a week. As is confirmed by data from the work travel survey (given in Chapter VI), many commuters use BART on some days and their cars (or other modes) on other days.

At the time of the 1976 survey, 28% of travelers had not made the trip surveyed before BART was operating. This high percentage tends to

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*Column 3 of Table 19 shows the distribution of BART trip characteristics as computed from data for the 6:00 a.m. to 3:00 p.m. period. These data slightly underrepresent peak trips and overrepresent off-peak trips because the survey period (intentionally) included most of the off-peak but only the morning peak period. Column 5 of Table 19 shows the corresponding distributions estimated for the entire 6:00 a.m. to midnight BART service day, with compensation made for the peak/off-peak bias. Comparison of columns 3 and 5 shows significant differences in the trip purpose distribution, work purpose trips being significantly higher in the total all-day estimate (66.8%) than in the total survey period estimate (58.8%). However, the distribution of other trip characteristics shown in columns 3 and 5 of Table 19 is generally close, suggesting that the biases attributable to the underrepresentation of peak-period travel are small as far as these other trip characteristics are concerned. Consequently, the percentages shown in Table 21 are valid when compared column by column.

reduce the reliability of the "previous travel mode" variable as an indicator of the mode that would likely be used if BART were not now available. Data on previous travel mode (among people who did travel previously) show that 56% used automobile (driving alone, carpooling, or using motorcycle), and 44% used transit or walked. The previous mode of BART travel is discussed more fully in Chapter VI (Table 33).

Peak and Off-Peak Trip Characteristics. As shown in Table 19, the characteristics of peak and off-peak trips are substantially different. The table shows that 87% of morning peak trips are work trips; only 28% of off-peak trips are work trips. There are proportionately fewer very long and very short trips in the peak, so the average travel time for peak and off-peak trips is similar (about 46 minutes). The proportion of trips diverted from bus or streetcar was higher for peak trips (45%) than off-peak trips (40%), reflecting the higher levels of bus service provided in the peak than off-peak periods.

East Bay, West Bay, and Transbay Trip Characteristics. As shown in Table 20, the percentage of work-purpose trips is higher for the West Bay (73%) than the East Bay (63%). Transbay trips are longest (54 minutes average travel time), followed by East Bay trips (46 minutes), and West Bay trips (34 minutes). The West Bay has the highest percentage of trips previously made by bus or streetcar (64%), followed by transbay (43%), and East Bay (26%). The high West Bay percentage reflects the relatively high levels of MUNI bus and streetcar services and high levels of transit ridership existing in San Francisco before BART.

Trip Characteristics by Purpose. Characteristics of BART trips according to trip purpose are shown in Table 21. Of school trips on BART, 57% are made in the East Bay. Of business trips on BART, 63% are made transbay. The total travel time distribution shows that business trips are generally the shortest (38 minutes), and school trips are the longest (51 minutes). Of the people who did not make the trip before BART, more were traveling to or from school than for any other reason, reflecting changes in the population attending school and college. Of work-purpose trips 45% were previously made by bus or streetcar; of business trips only 24% were previously made by bus or streetcar.

Modes of Getting to and from BART. Characteristics of BART trips according to the traveler's access mode (to the BART station) over the 6:00 a.m. to 3:00 p.m. survey period are shown in Table 22. Driving alone is the most-used access mode during the morning peak period, and walking is the most-used means of access during the off-peak period. Correspondingly, driving alone is the predominant access mode for work trips, and walking is the prevailing means of access for all other trip purposes. Access trips by bus are longer (14 minutes on average) than access trips by automobile (11 minutes) and walking (9 minutes).

Characteristics of BART trips according to egress mode (from the BART station) are compared in Table 23. During both the morning peak and off-peak periods, the primary means of getting from the BART station to the destination is by walking. Among all trips made to or from work during the 6:00 a.m. to 3:00 p.m. survey period, 80% are made from the BART station to the destination by walking.

Modes of getting to and from BART stations vary greatly depending on station location. In the suburban areas of the East Bay, the automobile is used predominantly. In the more densely developed residential areas of San Francisco and the East Bay cities, bus and walking are more important access modes. Overall, at the (home) origin end of the trip, 40% of BART travelers drive to and park at the station, 17% are dropped off by car, 20% get to the station by bus, and nearly all the remaining 23% walk. At the (nonhome) destination end of the trip, 78% of BART travelers walk from the station; and, reflecting BART's design goal of bringing people close to their downtown destinations, the percentage is higher still for the central San Francisco and Oakland stations.

BART access modes are shown station-by-station in Table 24. The percentages in the table are only for those travelers making the first leg of a round trip during the survey period (nearly all these are trips from home). The table illustrates the high percentage of trips for which the automobile is used as the means of getting to suburban East Bay stations.

Socioeconomic Characteristics of BART Tripmakers*

The socioeconomic characteristics of BART travelers, as estimated from the 1976 BART passenger profile survey, are analyzed in this section. Data are given in Tables 25, 26, and 27 at the end of the chapter.**

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*A more detailed analysis of BART traveler characteristics is given in Reference 11, pp. 21-29.

**Column 3 of Table 25 shows the socioeconomic characteristics distribution of BART travelers as computed from data for the total 6:00 a.m. to 3:00 p.m. survey period (representing 66,800 trips). As discussed earlier, these data slightly underrepresent peak and overrepresent off-peak trips. Column 5 of Table 25 (representing the 124,500 all-day trips) shows the corresponding socioeconomic distributions with compensation made for this bias. Comparison of the two columns shows that biases attributable to the underrepresentation of peak-period travel appear to be negligible. Consequently, all percentages given in Tables 26, 27, and 28 are based directly on data for the 6:00 a.m. to 3:00 p.m. survey period.

<u>Comparison with Service Area Population</u>. As a basis for assessing the equity of BART's ridership, the sex, age, education, income, and race of BART travelers may be compared with the distributions of the same characteristics for the population of the greater BART service area as a whole. BART rider distributions are given in Table 25 (column 5) and census distributions for the service area are given in Chapter III, Tables 7a and 7b. Table 7a gives census distributions of sex, age, family income,* and race (for the total population), and education level (for the population aged 25 years and older).** Table 7b gives census distributions of sex, age, and race only (for the population aged 16 years and older). Comparison of the BART rider data with the 16-and-over census data (where available) is appropriate because "under high school age" children were not sampled in the passenger profile survey.

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*Note that the census data give family income, while the BART passenger profile survey asked for household income. Not all households contain families because a household may be composed of a group of unrelated persons or one person living alone. As a result, in aggregate, household incomes are slightly lower than family incomes. However, the difference between the two is small enough that it does not affect the comparisons materially.

**Note that the comparison of education levels is complicated by the fact that the census distribution is only for those 25 years and older, while the BART rider distribution given in Tables 25 and 26 is for all those 16 years and older. The distribution of education level among BART riders aged 25 years and older (which emphasizes the conclusion that BART riders are better educated than the population as a whole) is as follows:

	Percent	Trips Represented 6:00 a.m.-3:00 p.m.
Less than high school	3.3%	1,600
High school graduate	14.4	7,000
Some college	33.9	16,400
4-year college graduate	18.2	8,800
More than 4 years college	30.2	14,700
	100.0%	48,500

Relative to the greater BART service area population, BART travelers include a slightly higher percentage of males, are younger, and are much better educated. Overall, the census and BART rider distributions of income are similar. With regard to race, BART riders include about the same proportion of blacks (11.3%) as is present in the adult population of the greater BART service area in total (10.5%), but BART riders include significantly fewer Spanish-Americans (5.8%) than are present in the census adult population (11.2%). However, the latter comparison may be misleading because of possible ambiguity in the distinction between "white" and "Spanish-American." For example, some people who are defined in the census as "Spanish-American" may well have indicated "white" as their race on the travel survey.

Of course, some of the differences between the characteristics of BART riders and the characteristics of the census population are attributable to the fact that the population of regular tripmakers (by BART and all other modes) is different from the total population. (Older people make fewer trips than younger people, for example.)

Peak and Off-Peak Travel. Tables 25 and 26 summarize BART rider characteristics by peak and off-peak travel, and trip purpose, respectively. As shown in Table 25, compared with off-peak travelers, peak-period travelers have a lower percentage of males, have higher family incomes, and are more likely to be in the 25-to-55 age bracket. Minorities make up a higher proportion of peak than off-peak ridership; however, the difference is not statistically significant at the 95% confidence level. Table 26 shows that a relatively high percentage of minority riders travel to or from school or college.

Minority Use of BART.* Table 27 summarizes the socioeconomic characteristics of BART riders according to their ethnic/racial category. As shown in the table, minority BART riders are typically much younger than white riders. This reflects the generally younger age profile of the minority community; also the greater minority use of BART for school and college trips (particularly among blacks and Asians).

The proportion of Asian BART riders having at least some college education (84%) is highest. This figure compares with 82% for whites, 77% for blacks, and 64% for Spanish-American persons. These percentages are all much higher than those for the areawide population. Whites and Asians who ride BART have the largest proportions of family incomes over $15,000 (50% and 49%, respectively). Among black and Spanish-American groups, the corresponding percentages are 33% and 32%, respectively. Although the percentage of nonwhite BART riders with incomes under $10,000 is higher than the percentage areawide, this is also the case with white riders and may be largely attributable to the high percentage of college age riders. The percentage of riders with middle range earnings ($10,000 to $14,999) is near the areawide average among both white and nonwhite BART riders.

Thus, the socioeconomic status of nonwhite BART riders is similar to the status of white riders. For the most part, minority riders on BART are not a particularly disadvantaged segment of the population. The distribution of destination stations of nonwhite riders is also much the same as for white riders, with emphasis on the downtown San Francisco stations, (although there are expected differences in the distribution of origin stations).

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*A detailed analysis of BART impacts on travel by ethnic minorities is given in Reference 14.

BART carries a relatively small percentage of low-income disadvantaged minority riders (also low-income disadvantaged white riders) largely as a function of where these segments of the population live and wish to travel within the urban area. BART was intended as a long-distance commuter service and provides the greatest accessibility improvements from the more remote (and typically affluent) suburbs to the downtown areas. Shorter trips within the central cities and inner suburban areas (where most of the low-income population live) are typically better served by bus.

Conclusions

The characteristics of trips made on BART reflect the service advantages it provides relative to bus or automobile. As intended, the predominant use of BART is for long-distance commute trips, particularly to workplaces in downtown San Francisco. These are the trips for which BART has improved peak-period transit travel times the most. About 67% of all BART trips made on weekdays are to and from work, and, consistent with this pattern, ridership tends to be heavily concentrated in the morning and evening peak periods. Patterns of ridership are also heavily "tidal" in character. For example, on the transbay link, which is the most heavily traveled on the System, 90% of peak-period trips are toward San Francisco and only 10% are in the reverse direction. The average journey to work by BART covers about 17 miles (13 miles on BART itself, and 4 miles to and from stations), much longer than the average 9-mile work journey by automobile.

The shortfall between BART's current ridership of 140,000 passenger trips per day and the much higher originally forecast ridership is explained in part by the shortcomings of current BART service which, as has been mentioned, can be expected to improve. However, it probably reflects as much, or more, on the optimism of the assumptions underlying the original forecasts, particularly on the door-to-door service levels it was assumed

BART would be capable of providing. Although BART has provided significant improvements in transit travel times for many long-distance commute trips, it provides door-to-door travel times competitive with the automobile for relatively few trips. In contrast to the assumptions of the early BART planners and publicists, this will probably continue to be the case even if originally anticipated BART service levels are achieved.

A lesson to be learned from the BART experience is that those predicting ridership on other rail systems must be careful to make realistic assessments of the level of service that can be provided in practice, and to recognize the intrinsic limitation of rail transit service when estimating travelers' mode choice decisions and ridership volumes. In particular, it must be recognized that the ability of a rail system to attract ridership is constrained, even under ideal service conditions, by the need for people to get to the train station, transfer between vehicles, and wait for trains.

Table 19

BART TRIP CHARACTERISTICS ACCORDING TO TIME PERIOD

Trip Characteristic	Time Period: Morning Peak Period (6:00 a.m. to 8:59 a.m.)	Off-Peak Period (9:00 a.m. to 3:00 p.m.)	Total Survey Period (6:00 a.m. to 3:00 p.m.)	Total Trips Represented During Survey Period	Total All Day (6:00 a.m. to 12:00 midnight)	Total All-Day Trips Represented
Trip Purpose						
Work	87.0%	27.8%	58.8%	39,300	66.8%	83,100
Business	0.2	6.6	3.3	2,200	2.4	3,000
School	8.9	15.6	12.1	8,100	11.2	13,900
Personal business	1.3	22.3	11.1	7,400	8.5	10,600
Other	2.6	27.7	14.7	9,800	11.1	13,900
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Travel Area						
East Bay	33.7%	32.7%	33.2%	21,800	33.3%	41,400
West Bay	26.0	24.2	25.1	16,900	24.8	30,900
Transbay	40.3	43.1	41.7	28,100	41.9	52,200
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Total Travel Time						
Under 16 minutes	4.1%	7.4%	5.6%	3,700	5.2%	6,500
16 to 30 minutes	23.3	27.7	25.2	16,800	24.7	30,800
31 to 45 minutes	26.9	21.6	24.5	16,400	25.5	31,700
46 to 60 minutes	28.6	21.4	25.4	17,000	25.7	32,000
Over 60 minutes	17.1	21.9	19.3	12,900	18.9	23,500
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Average in minutes	46.5	45.7	46.2		46.3	
Travel Time on BART						
Under 16 minutes	21.6%	29.6%	25.2%	16,800	24.0%	29,900
16 to 30 minutes	33.5	30.0	31.9	21,300	32.5	40,500
31 to 45 minutes	24.8	18.7	22.1	14,800	23.0	28,600
46 to 60 minutes	14.7	10.9	13.0	8,700	13.5	16,800
Over 60 minutes	5.4	10.8	7.8	5,200	7.0	8,700
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Average in minutes	33.3	33.2	33.2		33.2	
Travel Frequency						
5 days per week	76.2%	32.7%	55.3%	37,000	61.3%	76,400
3 to 4 days per week	12.7	17.7	15.1	10,100	14.4	17,900
1 to 2 days per week	4.7	17.3	10.8	7,200	9.0	11,200
Less than once per week	4.9	24.8	14.4	9,600	11.7	14,600
Trial trip	1.5	7.5	4.4	2,900	3.6	4,400
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Did you make this trip before BART was operating?						
Yes	70.9%	74.4%	72.6%	48,500	72.2%	89,800
No	29.1	25.6	27.4	18,300	27.8	33,700
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Previous Travel Mode						
Bus or streetcar	44.7%	40.1%	42.5%	20,600	43.1%	38,700
Drove alone	36.1	38.1	37.1	18,000	36.8	33,000
Car pool	16.9	18.8	17.9	8,700	17.6	15,800
Walk	0.7	1.9	1.2	600	1.1	1,000
Other	1.6	1.1	1.3	600	1.4	1,300
Total	100.0%	100.0%	100.0%	48,500	100.0%	89,800
Would you make this trip if BART were not operating?						
Yes	98.0%	93.6%	95.9%	64,100	96.5%	120,100
No	2.0	6.4	4.1	2,700	3.5	4,400
Total	100.0%	100.0%	100.0%	66,800	100.0%	124,500
Unweighted Sample Size	4,268	3,874	8,142		8,142	
Number of Trips Represented	34,400	32,400	66,800		124,500	
Percent of Trips Represented	27.6%	26.0%	53.7%		100.0%	

Note: Due to missing data, actual (weighted) responses calculated from column totals may not exactly sum to the row totals shown.

Source: 1976 BART Passenger Profile Survey.

Table 20

BART TRIP CHARACTERISTICS ACCORDING TO TRAVEL AREA

Trip Characteristic	Travel Area: East Bay	West Bay	Transbay	Total	Total All-Day Trips Represented
Time Period[a]					
Morning peak (6:00 a.m. to 9:00 a.m.)	27.3%	29.7%	28.3%	28.4%	34,400
Midday (9:00 a.m. to 3:00 p.m.)	26.7	23.9	23.7	24.7	32,400
Afternoon peak (3:00 p.m. to 7:00 p.m.)	38.3	40.7	38.9	39.2	47,600
Evening (7:00 p.m. to midnight)	7.7	5.7	9.1	7.7	10,100
Total	100.0%	100.0%	100.0%	100.0%	124,500
Trip Purpose					
Work	62.9%	72.8%	66.2%	66.8%	83,100
Business	1.0	2.3	3.7	2.4	3,000
School	18.7	7.9	7.1	11.2	13,900
Personal business	8.1	7.3	9.4	8.5	10,600
Other	9.3	9.7	13.6	11.1	13,900
Total	100.0%	100.0%	100.0%	100.0%	124,500
Total Travel Time					
Under 16 minutes	5.0%	7.5%	4.0%	5.2%	6,500
16 to 30 minutes	23.9	49.1	11.8	24.7	30,000
31 to 45 minutes	27.9	29.6	21.4	25.5	31,700
46 to 60 minutes	26.1	9.9	34.1	25.7	32,000
Over 60 minutes	17.1	3.9	28.7	18.9	23,500
Total	100.0%	100.0%	100.0%	100.0%	124,500
Average in minutes	45.8	33.6	53.7	46.3	
Travel Time on BART					
Under 16 minutes	21.7%	48.5%	9.6%	24.0%	29,900
16 to 30 minutes	35.5	42.2	24.5	32.5	40,500
31 to 45 minutes	24.9	6.1	32.0	23.0	28,600
46 to 60 minutes	11.0	1.6	22.9	13.5	16,800
Over 60 minutes	6.9	1.6	11.0	7.0	8,700
Total	100.0%	100.0%	100.0%	100.0%	124,500
Average in minutes	33.0	21.0	41.5	33.2	
Travel Frequency					
5 days per week	60.9%	69.4%	57.2%	61.3%	76,400
3 to 4 days per week	17.6	13.1	12.4	14.4	17,900
1 to 2 days per week	8.9	7.3	10.0	9.0	11,200
Less than once per week	10.2	7.6	15.3	11.7	14,600
Trial trip	2.4	2.6	5.1	3.6	4,400
Total	100.0%	100.0%	100.0%	100.0%	124,500
Did you make this trip before BART was operating?					
Yes	68.1%	79.0%	71.3%	72.2%	89,800
No	31.9	21.0	28.7	27.8	33,700
Total	100.0%	100.0%	100.0%	100.0%	124,500
Previous Travel Mode					
Bus or streetcar	25.9%	63.9%	42.6%	43.1%	38,700
Drove alone	50.9	19.4	37.7	36.8	33,000
Car pool	20.0	13.5	18.4	17.6	15,800
Walk	1.3	2.0	—	1.1	1,000
Other	1.9	1.2	1.3	1.4	1,300
Total	100.0%	100.0%	100.0%	100.0%	89,800
Would you make this trip if BART were not operating?					
Yes	96.4%	95.7%	97.0%	96.5%	120,100
No	3.6	4.3	3.0	3.5	4,400
Total	100.0%	100.0%	100.0%	100.0%	124,500
Unweighted Sample Size:	3,232	1,441	3,469	8,142	
Number of Trips Represented	41,400	30,900	52,200	124,500	
Percent of Trips Represented	33.3%	24.8%	41.9%	100.0%	

Note: Due to missing data, actual (weighted) responses calculated from column totals may not sum to the row totals shown.

a. Percentage distributions based on all-day ridership for October 1976.

Source: 1976 BART Passenger Profile Survey.

Table 21

BART TRIP CHARACTERISTICS ACCORDING TO TRIP PURPOSE

Trip Characteristic	Trip Purpose: Work	Business	School	Personal Business	Other	Total	Total Trips Represented During Survey Period
Time Period							
Morning peak (6:00 a.m. to 9:00 a.m.)	76.9%	3.1%	37.7%	5.8%	9.1%	51.5%	34,400
Midday (9:00 a.m. to 3:00 p.m.)	23.1	96.9	62.3	94.2	90.9	48.5	32,400
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Travel Area							
East Bay	31.2%	13.1%	56.6%	32.0%	27.2%	33.2%	21,800
West Bay	27.7	24.2	18.0	23.8	32.3	25.1	16,900
Transbay	41.1	62.7	25.4	44.2	40.5	41.7	28,100
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Total Travel Time							
Under 16 minutes	4.1%	10.5%	5.7%	8.7%	8.8%	5.6%	3,700
16 to 30 minutes	25.7	42.3	18.8	24.1	26.5	25.2	16,800
31 to 45 minutes	26.9	20.3	21.5	19.3	21.3	24.5	16,400
46 to 60 minutes	27.7	13.3	23.6	24.0	19.4	25.4	17,000
Over 60 minutes	15.6	13.6	30.4	23.9	24.0	19.3	12,900
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Average in minutes	45.4	38.2	51.1	47.1	46.1	46.2	
Travel Time on BART							
Under 16 minutes	23.4%	34.3%	25.7%	27.5%	29.2%	25.2%	16,800
16 to 30 minutes	34.1	35.2	26.6	27.4	29.7	31.9	21,300
31 to 45 minutes	23.9	14.6	21.8	18.0	18.3	22.1	14,800
46 to 60 minutes	13.8	8.0	13.9	13.2	9.0	13.0	8,700
Over 60 minutes	4.8	7.9	12.0	13.9	13.8	7.8	5,200
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Average in minutes	32.3	29.5	35.7	35.7	34.2	35.2	
Travel Frequency							
5 days per week	73.5%	27.4%	57.6%	13.6%	18.3%	55.4%	37,000
3 to 4 days per week	14.1	14.3	24.2	12.2	13.9	15.1	10,100
1 to 2 days per week	5.6	18.1	12.5	23.4	18.8	10.8	7,200
Less than once per week	5.2	35.0	4.7	42.7	33.4	14.4	9,600
Trial trip	1.6	5.2	1.0	8.1	15.6	4.4	2,900
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Did you make this trip before BART was operating?							
Yes	73.2%	76.3%	65.1%	81.6%	68.9%	72.6%	48,500
No	26.8	23.7	34.9	18.4	31.1	27.4	18,300
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Previous Travel Mode							
Bus or streetcar	45.0%	23.6%	40.7%	41.5%	38.1%	42.5%	20,600
Drove alone	37.6	58.5	37.1	34.9	32.1	37.1	18,000
Car pool	15.6	13.9	19.1	20.9	26.1	17.9	8,700
Walk	0.7	2.4	1.1	2.1	2.3	1.2	600
Other	1.1	1.6	2.0	0.6	1.4	1.3	600
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	48,500
Would you make this trip if BART were not operating?							
Yes	98.0%	91.3%	95.2%	95.0%	90.3%	95.9%	64,100
No	2.0	8.7	4.8	5.0	9.7	4.1	2,700
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Unweighted Sample Size	4,805	247	993	944	1,153	8,142	
Number of Trips Represented	39,300	2,200	8,100	7,400	9,800	66,800	
Percent of Trips Represented	58.8%	3.3%	12.1%	11.1%	14.7%	100.0%	

Note: Due to missing data, actual (weighted) responses calculated from column totals may not exactly sum to the row totals shown.

Source: 1976 BART Passenger Profile Survey.

Table 22

BART TRIP CHARACTERISTICS ACCORDING TO
MODE OF ACCESS TO BART STATION

Trip Characteristic	Access Mode							Total Trips Represented During Survey Period
	Bus	Drive Alone	Car Pool	Walk	Dropped Off	Other	Total	
Time Period								
Morning peak (6:00 a.m. to 9:00 a.m.)	17.2%	36.4%	5.7%	19.1%	20.1%	1.5%	100.0%	34,400
Midday (9:00 a.m. to 3:00 p.m.)	23.3	17.7	5.6	42.7	9.3	1.4	100.0	32,400
								66,800
Trip Purpose								
Work	16.9%	35.6%	5.0%	22.7%	18.2%	1.6%	100.0%	39,300
Business	7.8	17.4	2.2	65.5	6.3	0.8	100.0	2,200
School	30.3	17.5	1.7	36.2	12.3	2.0	100.0	8,100
Personal business	23.8	17.7	10.9	38.7	8.1	0.8	100.0	7,400
Other	24.8	11.9	8.6	42.2	11.0	1.5	100.0	9,800
								66,800
Travel Area								
East Bay	21.3%	28.8%	4.9%	28.4%	14.6%	2.0%	100.0%	21,800
West Bay	22.6	15.3	4.2	41.2	16.5	0.2	100.0	16,900
Transbay	17.5	33.8	7.2	25.2	14.5	1.8	100.0	28,100
								66,800
Access Travel Time								
Under 6 minutes	9.6%	26.0%	4.6%	37.2%	21.0%	1.6%	100.0%	24,400
6 to 10 minutes	17.2	29.6	5.7	31.8	14.2	1.5	100.0	22,600
11 to 15 minutes	30.0	30.8	7.2	20.0	10.7	1.3	100.0	10,000
16 to 20 minutes	39.3	24.3	4.5	22.0	9.2	0.7	100.0	4,700
Over 20 minutes	43.6	22.7	8.4	19.2	4.9	1.2	100.0	5,100
								66,800
Average in minutes	14.1	10.5	11.3	8.8	8.1	9.2	10.0	
Unweighted Sample Size	1,523	2,491	480	2,337	1,164	147	8,142	
Number of Trips Represented	13,400	18,400	3,800	20,200	10,000	1,000		66,800
Percent of Trips Represented	20.1%	27.6%	5.7%	30.2%	14.9%	1.5%		100.0%

Note: Due to missing data, actual (weighted) responses calculated from row totals may not exactly sum to the column totals shown.

Source: 1976 BART Passenger Profile Survey.

Table 23

BART TRIP CHARACTERISTICS ACCORDING TO
MODE OF EGRESS FROM BART STATION

Trip Characteristic	Egress Mode: Bus	Drive Alone	Car Pool	Walk	Picked Up	Other	Total	Total Trips Represented During Survey Period
Time Period								
Morning peak (6:00 a.m. to 9:00 a.m.)	14.7%	1.1%	0.6%	81.2%	1.9%	0.5%	100.0%	34,400
Midday (9:00 a.m. to 3:00 p.m.)	25.8	8.5	2.2	57.9	3.9	1.7	100.0	32,400
								66,800
Trip Purpose								
Work	14.0%	2.9%	0.7%	79.7%	2.2%	0.5%	100.0%	39,300
Business	6.6	9.6	0.5	77.6	3.7	2.0	100.0	2,200
School	38.5	8.7	0.8	48.2	2.2	1.6	100.0	8,100
Personal business	25.9	8.5	4.1	57.2	3.2	1.1	100.0	7,400
Other	28.1	4.2	2.6	57.0	5.7	2.4	100.0	9,800
								66,800
Travel Area								
East Bay	29.8%	4.7%	1.6%	59.0%	3.4%	1.5%	100.0%	21,800
West Bay	10.9	1.8	0.9	84.2	1.5	0.7	100.0	16,900
Transbay	17.7	6.3	1.4	70.5	3.2	0.9	100.0	28,100
								66,800
Egress Travel Time								
Under 6 minutes	7.2%	3.3%	1.1%	85.9%	2.0%	0.5%	100.0%	32,800
6 to 10 minutes	18.5	4.8	1.1	71.0	3.9	0.7	100.0	18,900
11 to 15 minutes	41.2	6.1	1.5	44.9	3.8	2.5	100.0	7,600
16 to 20 minutes	54.9	7.9	2.1	30.9	2.8	1.4	100.0	3,600
Over 20 minutes	59.2	8.7	3.7	21.0	3.3	4.1	100.0	3,900
								66,800
Average in minutes	14.0	11.1	12.0	7.2	9.8	14.5	8.9	
Unweighted Sample Size	1,669	326	106	5,740	220	81	8,142	
Number of Trips Represented	13,400	3,100	900	46,800	1,900	700		66,800
Percent of Trips Represented	20.0%	4.7%	1.4%	70.0%	2.8%	1.1%		100.0%

Note: Due to missing data, actual (weighted) responses calculated from row totals may not exactly sum to the column totals shown.

Source: 1976 BART Passenger Profile Survey.

Table 24

MODE OF ACCESS TO BART STATIONS

Station	Daily Patronage[a]	Entering First Leg of Trip[b]	Access Mode: Drive Alone	Car Pool	Dropped Off	Bus or Streetcar	Other[c]
Concord	4,547	3,033	44.7%	9.7%	22.6%	10.6%	12.4%
Pleasant Hill	3,539	1,755	45.4	8.2	22.1	7.1	17.2
Walnut Creek	3,661	2,090	46.3	9.4	18.1	10.6	15.6
Lafayette	2,112	1,355	53.9	9.7	20.9	0.0	15.5
Orinda	1,869	1,278	59.9	11.1	20.1	0.6	8.3
Rockridge	1,997	1,118	36.3	6.2	8.3	22.4	26.8
Richmond	1,513	811	27.9	5.3	16.5	24.3	26.0
El Cerrito del Norte	1,938	1,358	48.2	10.3	11.1	11.4	19.0
El Cerrito Plaza	1,332	1,042	29.5	4.8	9.4	12.7	43.6
North Berkeley	1,483	1,013	30.2	2.7	9.2	10.0	47.9
Berkeley	5,629	1,603	4.3	0.0	4.5	33.3	57.9
Ashby	1,400	752	20.9	5.1	9.7	12.1	52.2
Fremont	3,439	2,019	50.7	12.4	12.3	18.5	6.1
Union City	2,367	1,455	56.1	7.6	12.6	15.3	8.4
South Hayward	1,950	1,094	45.3	6.5	22.9	7.7	17.6
Hayward	3,411	1,604	45.3	6.0	15.6	22.0	20.1
Bay Fair	2,685	1,742	50.6	11.4	14.8	14.2	9.0
San Leandro	2,204	1,079	41.6	8.6	16.5	16.5	16.8
Coliseum	2,020	880	34.1	3.4	13.8	33.8	14.9
Fruitvale	2,902	1,433	42.2	4.4	11.9	27.8	13.7
Lake Merritt	3,281	1,078	28.2	5.7	17.9	10.3	37.9
MacArthur	2,016	1,033	37.6	5.1	13.1	18.6	25.6
19th Street Oakland	5,633	1,244	11.5	4.2	8.2	27.6	48.5
12th Street Oakland	4,632	1,024	7.5	0.9	5.2	56.0	30.4
Oakland West	1,824	945	59.1	10.7	14.9	4.8	10.5
Daly City	8,084	4,615	21.8	6.6	27.3	31.0	13.3
Balboa Park	4,482	2,325	25.3	6.9	23.1	11.5	33.2
Glen Park	3,612	2,654	22.8	4.5	21.5	18.5	32.7
24th Street Mission	3,210	1,533	5.2	2.2	11.8	18.1	62.7
16th Street Mission	2,281	1,075	6.8	1.3	10.6	16.4	64.9
Civic Center	7,607	1,433	5.3	0.8	2.8	42.6	48.5
Powell	11,031	2,081	3.2	1.0	4.5	48.5	42.8
Montgomery	16,237	1,388	3.9	1.5	5.6	28.0	61.0
Embarcadero[d]	9,486						

a. The total number of people entering the BART station for a typical day, February, 1977.
b. The number of BART travelers entering the BART station from 6:00 a.m. to 3:00 p.m. who were making the first leg of a round trip (nearly all from home).
c. "Other" includes bicycle, motorcycle, and walking.
d. The Embarcadero Station was not open at the time of the survey.

Source: 1976 BART Passenger Profile Survey.

Table 25

SOCIOECONOMIC CHARACTERISTICS OF BART TRAVELERS
ACCORDING TO TIME PERIOD

Socioeconomic Characteristic	Time Period: Morning Peak Period (6:00 a.m. to 8:59 a.m.)	Time Period: Off-Peak Period (9:00 a.m. to 3:00 p.m.)	Time Period: Total Survey Period (6:00 a.m. to 3:00 p.m.)	Total Trips Represented During Survey Period	Total All Day (6:00 a.m. to 12:00 midnight)	Total All-Day Trips Represented
ex						
Male	49.2%	53.9%	51.5%	34,400	50.8%	63,300
Female	50.8	46.1	48.5	32,400	49.2	61,200
	100.0%	100.0%	100.0%	66,800	100.0%	124,500
ge						
16 to 17	1.7%	3.1%	2.4%	1,600	2.2%	2,700
18 to 24	21.6	28.7	25.0	16,700	24.0	29,900
25 to 34	36.6	30.9	33.8	22,600	34.7	43,100
35 to 54	31.5	22.6	27.2	18,100	28.5	35,400
55 to 64	6.6	7.4	7.0	4,700	6.9	8,600
Over 64	2.0	7.3	4.6	3,100	3.8	4,800
	100.0%	100.0%	100.0%	66,800	100.0%	124,500
ducation Level						
Less than high school	3.3%	6.2%	4.7%	3,200	4.3%	5,400
High school graduate	14.7%	15.6%	15.1%	10,100	15.0	18,700
Some college	39.9	40.0	40.0	26,700	39.9	49,700
4-year college graduate	18.4	15.1	16.8	11,200	17.3	21,500
More than 4 years of college	23.7	23.1	23.4	15,600	23.5	29,200
	100.0%	100.0%	100.0%	66,800	100.0%	124,500
nnual Household Income						
Under $7,000	12.4%	27.0%	19.4%	13,000	17.4%	21,600
$7,000 to $9,999	12.3	12.7	12.5	8,400	12.4	15,500
$10,000 to $14,999	19.2	18.0	18.6	12,400	18.8	23,400
$15,000 to $24,999	32.7	25.2	29.1	19,400	30.1	37,500
$25,000 and over	23.4	17.1	20.4	13,600	21.3	26,500
	100.0%	100.0%	100.0%	66,800	100.0%	124,500
thnic/Racial Category						
White	71.7%	73.5%	72.7%	48,600	72.3%	90,000
Black	11.5	10.9	11.2	7,500	11.3	14,100
Spanish-American	5.5	6.4	5.9	3,900	5.8	7,200
Asian	9.7	7.1	8.4	5,600	8.8	11,000
Other	1.6	2.1	1.8	1,200	1.8	2,200
	100.0%	100.0%	100.0%	66,800	100.0%	124,500
nweighted Sample Size	4,278	3,864	8,142		8,142	
umber of Trips Represented	34,400	32,400	66,800		124,500	
ercent of Trips Represented	27.6%	26.0%	53.7%		100.0%	

ote: Due to missing data, actual (weighted) responses calculated from column totals may not exactly sum to the row totals shown.

ource: 1976 BART Passenger Profile Survey.

Table 26

SOCIOECONOMIC CHARACTERISTICS OF BART TRAVELERS
ACCORDING TO TRIP PURPOSE

Socioeconomic Characteristic	Purpose: Work	Business	School	Personal Business	Other	Total	Total Trips Represented During Survey Period
Sex							
Male	51.2%	76.8%	53.2%	43.8%	51.3%	51.5%	34,400
Female	48.8	23.2	46.8	56.2	48.7	48.5	32,400
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Age							
16 to 17	0.5%	0.4%	8.1%	3.7%	4.4%	2.4%	1,600
18 to 24	18.8	3.8	60.2	20.8	29.0	25.0	16,700
25 to 34	38.1	44.6	24.7	25.0	28.8	33.8	22,600
35 to 54	33.0	38.8	6.2	23.7	21.2	27.2	18,100
55 to 64	7.0	10.5	0.4	11.3	8.1	7.0	4,700
Over 64	2.6	1.9	0.4	15.5	8.5	4.6	3,100
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Education Level							
Less than high school	3.0%	0.8%	6.7%	10.1%	6.7%	4.7%	3,200
High school graduate	15.1	10.3	8.3	20.3	17.4	15.1	10,100
Some college	37.9	21.3	61.5	35.1	39.6	40.0	26,700
4-year college graduate	18.8	24.9	8.7	15.8	14.1	16.8	11,200
More than 4 years of college	25.2	42.7	14.8	18.7	22.2	23.4	15,600
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Annual Household Income							
Under $7,000	12.3%	6.8%	39.2%	26.9%	30.0%	19.4%	13,000
$7,000 to $9,999	12.5	5.8	13.1	11.8	13.5	12.5	8,400
$10,000 to $14,999	19.6	8.6	16.4	20.2	17.5	18.6	12,400
$15,000 to $24,999	32.7	36.0	19.5	25.2	23.3	29.1	19,400
$25,000 and over	22.9	42.8	11.8	15.9	15.7	20.4	13,600
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Ethnic/Racial Category							
White	72.5%	83.1%	62.8%	77.2%	75.1%	72.7%	48,600
Black	11.9	6.4	14.1	8.3	9.9	11.2	7,500
Spanish-American	6.1	3.1	5.7	6.8	5.1	5.9	3,900
Asian	8.2	5.5	14.5	5.6	7.0	8.4	5,600
Other	1.3	1.9	2.9	2.1	2.9	1.8	1,200
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66,800
Unweighted Sample Size	4,805	247	993	944	1,153	8,142	
Number of Trips Represented	39,300	2,200	8,100	7,400	9,800	66,800	
Percent of Trips Represented	58.8%	3.3%	12.1%	11.1%	14.7%	100.0%	

Note: Due to missing data, actual (weighted) responses calculated from column totals may not exactly sum to the row totals shown.

Source: 1976 BART Passenger Profile Survey.

Table 27

SOCIOECONOMIC CHARACTERISTICS OF BART RIDERS
ACCORDING TO ETHNIC/RACIAL CATEGORY

Socioeconomic Characteristic	Asian	Black	Spanish-American	White	Other	Total
Sex						
Female	53.9%	56.6%	53.4%	43.8%	54.4%	48.5%
Male	46.1	43.4	46.6	56.2	45.6	51.5
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Age						
16 to 17	1.9%	3.0%	3.7%	2.1%	7.3%	2.4%
18 to 24	38.7	32.6	30.6	22.0	39.1	25.0
25 to 34	35.0	37.4	32.5	33.7	33.1	33.8
35 to 44	11.0	14.3	16.0	15.0	10.1	14.7
45 to 54	10.0	9.8	10.3	13.3	6.7	12.5
55 to 64	2.4	2.5	6.1	8.4	1.7	7.0
65 and Over	1.0	0.5	0.9	5.7	2.0	4.6
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Education Level						
Less than high school	3.0%	5.2%	10.6%	4.3%	7.3%	4.7%
High school graduate	12.7	17.9	25.7	13.9	14.1	15.1
Some college	41.2	53.5	40.7	37.0	48.9	40.0
4-year college graduate	21.6	12.0	12.4	18.1	9.5	16.8
More than 4 years college	21.4	11.4	10.5	26.6	20.1	23.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Annual Household Income, 1975						
Under $7,000	18.5%	24.5%	24.4%	18.5%	37.4%	19.4%
$7,000 to $9,999	12.4	19.0	18.9	10.5	17.0	12.5
$10,000 to $14,999	19.3	22.1	23.7	17.9	16.0	18.6
$15,000 to $19,999	15.3	13.1	14.0	14.5	7.7	14.4
$20,000 to $24,999	17.6	9.4	10.4	15.6	8.4	14.9
$25,000 and Over	16.2	10.9	7.4	20.0	10.8	20.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Unweighted Sample Size	562	716	407	5,789	668	8,142
Number of Trips Represented	5,600	7,500	3,900	48,600	1,200	66,800
Percent of Trips Represented	8.4%	11.2%	5.9%	72.7%	1.8%	100.0%

Source: 1976 BART Passenger Profile Survey.

BART IMPACTS

VI. IMPACTS ON MODAL SPLIT

In this chapter, BART's share of travel is analyzed in various travel markets and corridors, both areawide and within the primary BART service area. The likely without-BART modal distribution of trips is estimated by analyzing (1) the previous travel modes of BART riders and (2) their current alternative modes. BART's impacts on the distribution of travel between public transit and private automobile are also assessed.

BART's Share of Areawide Trips

Table 28 shows total weekday trips in the greater BART service area, distributed by mode (BART, automobile driver, automobile passenger, and bus or streetcar) and by trip purpose (work, business, school, shopping, and other) as estimated from the 1975 areawide travel survey.

Overall, BART's share of total weekday trips is by far the smallest of the four modes: about 118,000 trips per weekday (in May 1975) or approximately 2.4% of the estimated total 4,936,000 trips made by all modes. About 10.6% of total trips are made on bus or streetcar, and the remaining 87.0% are made by automobile (and other vehicle modes).

When total weekday trips in the greater BART service area are stratified by trip purpose, BART's largest share is for trips to and from work (5.2% of all work trips). Its second largest share is for school or college trips (2.9%); business trips rank third (1.9%). BART is used for a negligible share (less than 1%) of shopping or other-purpose trips. Corresponding to BART's relatively high share of work trips, its share of trips is also relatively high in the peak periods. Of all trips starting between 7:00 a.m. and 9:00 a.m. or 3:00 p.m. and 6:00 p.m., BART carries 3.8%, compared with 1.5% during the rest of the day.

As discussed in Chapter IV, BART provides the greatest travel time advantages for long-distance trips. Accordingly, it has a greater share

Table 28

MODE AND PURPOSE OF TRAVEL
(Total Trips per Weekday Made in Vehicles, May 1975)

Trip Purpose	Mode of Travel: BART	Automobile Driver	Automobile Passenger	Bus or Streetcar	Total All Modes
To and from Work	76,200 5.2%	955,800 65.6%	167,600 11.5%	258,200 17.7%	1,457,800 100.0%
Business	6,600 1.9%	292,400 86.2%	21,600 6.4%	18,600 5.5%	339,200 100.0%
School or College	15,400 2.9%	351,600 66.2%	65,000 12.3%	98,800 18.6%	530,800 100.0%
Shopping	5,800 0.6%	757,600 78.5%	155,400 16.1%	46,000 4.8%	964,800 100.0%
Other Purposes[a]	13,600 0.8%	1,185,200 72.1%	340,400 20.7%	104,200 6.4%	1,643,400 100.0%
Number of Trips Represented	117,600[b]	3,542,600[c]	750,000	525,800	4,936,000[d]
Percent of Trips Represented	2.4%	71.8%	15.2%	10.6%	100.0%
Unweighted Sample Size	9,698	1,183	262	192	

a. Other purposes include recreation trips, trips to visit friends or relatives, and personal business trips.
b. Average number of BART trips per weekday, May 1975.
c. Includes 166,800 trips per weekday made in pickup trucks, other commercial vehicles, and by motorcycles.
d. Estimated total number of person-trips made in vehicles per weekday by members of households in the greater BART service area, May 1975.

Sources: BART Impact Program, 1975 Areawide Travel Survey.
1975 BART Passenger Profile Survey.

of long trips than of short trips. The average work trip by BART, about 17 miles door-to-door, is nearly twice as long as the 9-mile average for all work trips made in vehicles in the greater BART service area. BART's larger share of long-distance trips is also indicated in Table 29, which shows mode shares for areawide trips according to the time spent traveling.

As trip times increase, so does BART's share of total areawide travel. For trips under 16 minutes, BART is used for a negligible 0.2% of trips represented by the areawide travel survey; for trip times in the range of 56 to 75 minutes, BART accounts for 13.2% of areawide trips; and for trip times over 75 minutes, BART's share climbs to 20.0% (albeit the total number of these very long trips is small). Similarly, the highest shares for buses and streetcars are for long trips, and correspondingly, automobile's highest share is for short trips. In part, the higher travel times of transit trips reflect their slower effective door-to-door speed. However, the high travel times also indicate longer trip distances. Most of the very long trips made on BART are trips to or from work, school, or college.

The discussion in this section has considered travel from all origins in the greater BART service area, for all trip purposes, and for 7-days-a-week travel. It should come as no surprise to find that the 71-mile BART System operating only 5 days a week (at the time of the survey) is used for only a small percentage of these areawide trips. The discussion in the following section focuses on BART's share of trips in its more immediate service area and for the trips it was principally designed to serve (journeys to work), as reported in the 1977 work travel survey.

BART's Share of Journey-to-Work Trips

The work travel survey sampled 8,400 workers who make trips to workplaces in the survey area. A total of 506,000 daily work trips are

Table 29

MODE OF TRAVEL AND TIME SPENT TRAVELING
(Total Trips per Weekday Made in Vehicles, May 1975)

Time Spent Traveling	Mode of Travel				Total All Modes
	BART	Automobile Driver[a]	Automobile Passenger	Bus or Streetcar	
Less than 16 minutes	6,400 0.2%	2,316,800 82.0%	365,200 12.9%	138,800 4.9%	2,827,200 100.0%
16 to 35 minutes	35,600 2.3%	956,600 62.7%	258,000 16.9%	275,400 18.1%	1,525,600 100.0%
36 to 55 minutes	33,200 11.2%	120,400 40.6%	87,000 29.4%	55,800 18.8%	296,400 100.0%
56 to 75 minutes	28,800 13.2%	113,400 51.8%	22,600 10.3%	54,200 24.7%	219,000 100.0%
More than 75 minutes	13,600 20.0%	35,400 52.2%	17,200 25.4%	1,600 2.4%	67,800 100.0%
Number of Trips Represented	117,600[b]	3,542,600	750,000	525,800	4,936,000[c]
Percent of Trips Represented	2.4%	71.8%	15.2%	10.6%	100.0%
Unweighted Sample Size	8,142	1,183	262	192	

a. Includes 166,800 trips per weekday made in pickup trucks, other commercial vehicles, and by motorcycles.

b. Average number of BART trips per weekday, May 1975.

c. Estimated total number of person-trips made in vehicles per weekday by members of households in the greater BART service area, May 1975.

Sources: BART Impact Program 1975 Areawide Travel Survey.
1976 BART Passenger Profile Survey, adjusted to reflect May 1975 BART service hours.

represented by this sample. Of the total, 59% or 298,000 daily trips to work are from residences in the five-corridor primary BART service area (see Figure 6, Chapter III). The survey included an estimated 66,000 daily trips to work by BART.*

Nearly half the 506,000 daily work trips covered in the work travel survey are to destinations in the central business districts (CBDs) of San Francisco (178,000 trips, 35% of the survey total) or Oakland (61,000 trips, 12%). Workplaces in the industrial areas of San Leandro and other parts of the BART Fremont Line survey area are also the destinations for a large number of surveyed work trips (126,000 trips, 25%). The remainder (141,000 trips, 28%) are to workplace destinations in non-CBD areas of San Francisco and Oakland and to areas served by the Richmond and Concord Lines. For trips to work beginning in the five corridors of the primary BART service area, the largest origin-to-destination work trip volumes are the 71,000 trips between origins and destinations on the Fremont Line and the 64,000 trips from the Daly City Corridor to the San Francisco CBD.

Table 30 shows journey-to-work mode shares by origin-to-destination travel corridor for BART, bus, automobile, and other modes. Overall, BART's share of trips for the entire work travel survey is 13%, compared with bus, 17%; automobile, 61%; and other modes, 9% (including walk trips, 6%). Considering only trips to work that begin within the five-corridor primary BART service area, the shares are: BART 15%; bus, 14%; automobile, 59%; and other modes, 12% (including walk trips, 9%). Considering only trips made by BART, bus, or automobile, the shares are BART 18%, bus 16%, and automobile 66%.

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*The 66,000 trips shown by the survey as the number usually made by BART is higher than the actual number of round-trip work trips made by BART on a typical day (currently about 50,000). The reason is that, on any given day, many travelers who usually ride BART decide instead to drive or use some other means of transport to get to or from work.

Table 30

MODAL DISTRIBUTION OF WORK TRIPS BY ORIGIN-DESTINATION CORRIDOR

Origin Residence Area	Usual Mode to Work	Destination Workplace Area: San Francisco CBD	San Francisco Other	Oakland CBD	Oakland Other	Richmond Line	Concord Line	Fremont Line	Total All Destinations
Daly City Corridor	BART	19.9%	7.7%	48.2%	13.4%				18.2%
	Bus	29.9	16.8	--	16.3	*	*	*	26.7
	Auto	32.3	46.1	51.8	70.2				36.2
	Other	17.8	29.4	--	--				18.8
Oakland Corridor	BART	21.1%		8.2%	6.6%	9.4%		15.1%	11.3%
	Bus	39.2	*	27.3	12.6	9.5	*	8.4	19.4
	Auto	39.7		42.4	63.3	68.6		73.5	56.8
	Other	--		22.1	17.4	12.6		3.1	12.6
Richmond Corridor	BART	13.3%		29.2%	3.3%	10.6%		11.3%	12.4%
	Bus	53.2	*	16.1	5.1	6.8	*	2.1	13.3
	Auto	33.5		53.8	81.9	54.1		86.6	59.1
	Other	--		0.9	9.7	28.6		--	15.2
Concord Corridor	BART	53.0%		41.4%	7.1%	11.8%	5.6%	11.2%	22.2%
	Bus	10.9	*	--	1.4	--	2.0	--	2.9.
	Auto	36.1		54.4	87.2	82.6	80.7	83.6	68.4
	Other	--		4.2	4.2	5.5	11.6	5.2	6.5
Fremont Corridor	BART	32.7%		32.4%	14.0%	23.8%		7.0%	13.3%
	Bus	25.8	*	20.8	3.3	2.1	*	3.4	7.2
	Auto	40.2		41.7	82.0	72.2		81.5	73.0
	Other	1.3		5.1	0.7	1.9		8.1	6.5
Subtotal All Corridors (Primary BART Service Area)	BART	23.4%	11.3%	26.6%	8.2%	11.7%	6.6%	8.2%	15.5%
	Bus	29.6	16.9	17.8	6.9	6.4	1.8	3.8	14.3
	Auto	33.7	46.9	46.0	76.4	60.7	81.2	80.9	58.6
	Other	13.3	24.9	9.6	8.5	21.2	10.4	7.1	11.6
BART Express Bus Area[a]	BART	38.2%		21.8%	--%	7.5%	2.6%	8.2%	11.2%
	Bus	18.6	*	2.1	1.7	1.7	3.0	--	3.9
	Auto	42.0		76.1	98.3	90.7	93.2	91.8	84.1
	Other	1.2		--	--	--	1.1	--	0.8
Other Areas	BART	9.7%	6.7%	21.2%	6.3%	12.8%	5.7%	4.4%	9.4%
	Bus	41.4	17.0	16.7	8.0	7.2	--	4.2	24.5
	Auto	41.5	70.9	61.1	83.4	71.7	91.0	86.3	60.4
	Other	7.4	5.3	1.0	2.2	8.2	3.3	5.1	5.8
Total All Origins	BART	16.9%	9.4%	24.7%	7.2%	11.6%	5.3%	7.1%	13.1%
	Bus	35.2	16.8	16.4	7.0	6.2	1.8	3.7	17.3
	Auto	37.8	57.1	52.4	79.7	66.1	86.5	82.9	60.6
	Other	10.1	16.7	6.5	6.2	16.1	6.4	6.3	9.0
Number of Trips		177,700	27,300	61,100	39,100	40,300	34,000	126,500	506,000
Percent of Trips		35%	5%	12%	8%	8%	7%	25%	100%

Note: Percentages shown in each origin-destination block are the percentages of origin-destination work trips by all modes made by (1) BART, (2) bus or streetcar, (3) automobile, truck, or motorcycle, and (4) other modes. For example, the block of percentages in the top left corner shows that, of the total work trips made from residences in the Daly City Corridor to workplaces in the San Francisco CBD, 19.9% are made by BART, 29.9% are made by bus (or streetcar), 32.3% are made by automobile (or truck or motorcycle), and 17.8% are made by other modes.

a. The BART Express Bus Area defines approximately the areas in Alameda and Contra Costa Counties that are served by the BART Express Bus lines. See Figure 9, Chapter III.

*Indicates that less than 1,000 daily trips are made by all modes combined.

Source: BART Impact Program, 1977 Work Travel Survey.

Table 30 shows that, within the work travel survey total, BART's share of trips to the San Francisco and Oakland CBDs is much higher than to non-CBD workplace areas. BART's share of trips to workplaces in the Oakland CBD is 25%, and its share of trips to workplaces in the San Francisco CBD is 17%. Considering only trips made from origins within the five-corridor primary BART service area, BART's share of CBD trips is higher still; 27% of trips to the Oakland CBD and 23% of trips to the San Francisco CBD are made by BART.

Table 30 also confirms that BART's trip shares are greatest for long trips, such as those from the Concord Corridor to the San Francisco CBD (where BART's share is 53%); from the Daly City Corridor to the Oakland CBD (49%); from the Concord Corridor to the Oakland CBD (41%); from the Fremont Corridor to the San Francisco CBD (33%); and from the Fremont Corridor to the Oakland CBD (32%). BART's share is smallest for short within-corridor trips, such as those from the Daly City Corridor to non-CBD San Francisco workplaces (8%); from the Oakland Corridor to the Oakland CBD (8%); and from the Oakland Corridor to non-CBD Oakland workplaces (7%).

<u>San Francisco CBD Trips</u>. Of work trips from the Daly City Corridor to the San Francisco CBD, 50% are made by public transit (20% BART, 30% bus). Another 15% of workers usually walk to work. In the East Bay, Table 30 shows marked differences among the mode distributions for travel to the San Francisco CBD from the various corridors. The BART-plus-bus transit share is not much different among the four East Bay-to-San Francisco CBD corridors, but the split between BART and bus varies a great deal.

For trips from the Concord Corridor to the San Francisco CBD, transit travel is mostly by BART (53% of all trips) and 11% by bus. This reflects the availability of direct transbay BART service, relatively infrequent Greyhound parallel bus service, and heavy automobile traffic through the Caldecott Tunnel. In contrast, for travel from the Richmond Corridor to the San Francisco CBD, BART's share is very small (13%), compared with the bus share (53%). This reflects the lack of direct Richmond-to-San Francisco BART service and the availability of good AC Transit transbay bus service.

West Bay, Transbay, and East Bay Trips. Table 31 details mode shares for work trips from origins in the five-corridor primary BART service area by West Bay, transbay, and East Bay travel. BART's share is by far the highest in the transbay corridor (32%); so, too, is the BART-plus-bus transit total (57%). The proportion of carpoolers in the automobile total is also much higher for the San Francisco-Oakland Bay Bridge, reflecting the congested traffic conditions on the bridge and the toll-free priority lanes reserved for carpools at the toll plaza.

The transbay mode distribution shown in Table 31 (BART, 32%; bus, 25%; drive alone, 33%; carpool, 10%) may be compared with the modal distribution of transbay work trips as surveyed in the 1974 transbay survey (BART, 21%; bus, 17%; automobile driver, 46%; automobile passenger, 16%).* The much higher transit percentages given by the work travel survey result from the different populations surveyed: the transbay survey covered all transbay trips, not just those destined for workplaces in the CBD-dominated work travel survey area.

BART's Share of its Potential Work Trip Market

Although the work travel survey was conducted in zones which are, for the most part, reasonably close to a BART station, some workplaces in

*A detailed discussion of BART's share of transbay travel by purpose, time-of-day, and origin-destination corridor is given in Reference 5, pp. 55-74.

Table 31

MODAL DISTRIBUTION OF WORK TRIPS:
WEST BAY, TRANSBAY, AND EAST BAY

Usual Mode	Trips Within West Bay	Transbay Trips	Trips Within East Bay	Total
BART	18%	32%	12%	16%
Bus or Streetcar	28	25	7	14
Drive Alone or With Family	29	33	65	52
Carpool	6	10	6	6
Walk	17	--	7	9
Other Modes	2	--	3	3
	100%	100%	100%	100%
Total Trips Represented	77,166	29,519	191,565	298,250

Note: Only work trips from origins within the primary BART service area are represented.

Source: BART Impact Program, 1977 Work Travel Survey.

the survey area are not effectively served by BART. Similarly, the home locations of many work travelers, even if inside the primary BART service area, are considerable distances from BART, especially in outlying suburban areas where zones are very large. Consequently, a large number of work trips surveyed are not really effectively served by BART.

In an attempt to give a picture of BART's market share relative to the trips it might reasonably be expected to carry, Table 32 shows BART trip shares expressed as a percentage of the total number of trips for which BART is possible as well as its share of all trips. All work trips made by respondents who answered "yes" to the question "Is it possible for you to travel to work on BART?" are considered as "BART possible" trips in this analysis. Obviously this definition depends on travelers' perceptions and knowledge of the BART System and bus connections to it, which vary from person to person. Nevertheless, the percentages shown in Table 32 do give a useful indication of BART's performance relative to its potential. Of the 506,000 daily work trips represented in the work travel survey, 167,000 or 33% are considered possible BART trips. Among the 298,000 trips made from residences in the primary BART service area, 118,000 or 40% are considered possible by BART.

The two sets of percentages in the table give rather different pictures of BART's effective modal shares in the various corridors. Although BART's share of total trips from the Oakland Corridor (11%) is half that for trips from the Concord Corridor (22%), BART trips expressed as a percentage of "BART possible" trips are similar for the two areas (37% and 36%, respectively). The different relationships between the two pairs of percentages ("total" and "BART possible") reflect the fact that the size of the zones and availability of access modes are different for the two areas. Of work trips made by people living in the area defined as the Concord Corridor, 62% are regarded as being possible by BART; of those made by people living in the Oakland Corridor, only 30% are regarded as possible by BART.

Table 32

BART'S SHARE OF TOTAL AND POTENTIAL WORK TRIPS BY ORIGIN-DESTINATION CORRIDOR

	Destination Workplace Area							
Origin Residence Area	San Francisco CBD	San Francisco Other	Oakland CBD	Oakland Other	Richmond Line	Concord Line	Fremont Line	Total
Daly City Corridor	19.9% 51.9	7.7% 34.1	48.2% 54.6	13.4% 17.9	*	*	*	18.2% 48.2
Oakland Corridor	21.1% 25.6	*	8.2% 61.2	6.6% 57.1	9.4% 26.2	*	15.1% 41.8	11.3% 37.3
Richmond Corridor	13.3% 16.2	*	29.2% 35.5	3.3% 9.8	10.6% 46.1	*	11.3% 17.4	12.4% 27.4
Concord Corridor	53.0% 54.9	*	41.4% 43.8	7.1% 9.1	11.8% 14.9	5.6% 27.8	11.2% 13.4	22.2% 35.8
Fremont Corridor	32.7% 40.5	*	32.4% 44.7	14.0% 28.8	23.8% 51.3	*	7.0% 35.2	13.3% 39.0
Subtotal All Corridors (Primary BART Service Area)	23.4% 45.8	11.3% 35.7	26.6% 44.6	8.2% 20.4	11.7% 35.2	6.6% 27.2	8.2% 32.0	15.5% 38.9
BART Express Bus Area[a]	38.2% 41.9	*	21.8% 26.9	*	7.5% 18.0	2.6% 42.2	8.2% 25.2	11.2% 28.8
Other Areas	9.7% 56.4	6.7% 59.3	21.2% 45.2	6.3% 28.6	12.8% 46.0	5.7% 46.9	4.4% 20.6	9.4% 44.2
Total	16.9% 48.2	9.4% 40.7	24.7% 43.1	7.2% 21.0	11.6% 35.6	5.3% 31.4	7.1% 28.9	13.1% 39.5
Total Number of Trips	177,700	27,300	61,100	39,100	40,300	34,000	126,500	506,000
Number of Trips for which BART is Possible	62,500	6,300	35,100	13,400	13,200	5,700	31,000	167,200
Number of BART Trips	30,100	2,500	15,100	2,800	4,700	1,800	9,000	66,000

Note: In each pair of figures, the first figure shows BART trips as a percentage of total origin-destination trips by all modes. The second figure shows BART trips as a percentage of all origin-destination trips for which BART is possible. For example, as shown by the top left pair of figures in the table, of all work trips made from the Daly City Corridor to the San Francisco CBD, 19.9% are made by BART. Of work trips from the Daly City Corridor to the San Francisco CBD for which BART is considered possible, BART carries 51.9%.

a. The BART Express Bus Area defines approximately the areas in Alameda and Contra Costa Counties that are served by the BART Express Bus lines. See Figure 9, Chapter III.

*Indicates that less than 1,000 daily trips are made by all modes combined.

Source: BART Impact Program 1977 Work Travel Survey.

For work trips from the Concord Corridor to the San Francisco CBD, BART's share of actual trips (53%) is almost as high as its share of potential trips (55%), because BART is regarded as a possible alternative by virtually all commuters. By contrast, BART's share of potential trips from the Daly City Corridor to the San Francisco CBD (52%) is much higher than its share of actual trips (20%), because BART is regarded as a possible alternative by a smaller proportion of commuters. For trips from all corridors, BART is the first choice mode for 39% of all trips that could (according to the assumptions of this analysis) possibly be made by BART.

Comparison of the socioeconomic characteristics of people who do and do not consider BART as a possible travel mode largely reflects the extent to which BART is oriented to downtown workplaces. Among the respondents who do consider BART a possible mode, 76% are in the "Professional and Technical," "Proprietors, Managers and Officers," or "Clerical" categories, 66% have some college education, and 48% have annual family incomes of $20,000 or more. Among the respondents who do not consider BART a possible mode, the percentages are 54%, 50%, and 36%, respectively.

Without-BART Mode Distribution

Estimating BART's impacts on travel volumes by other modes in the transportation system requires that assumptions be made about the modes BART travelers would use if BART were not available. Estimates of without-BART mode distributions have been developed from information about (1) the previous mode of current BART travelers, and (2) the second choice (alternative) mode of current BART travelers.

Previous Mode of BART Travelers. Table 33 shows the mode of travel previously used by BART travelers surveyed in each of the 4 years 1973-1976. Results for East Bay, West Bay, and transbay are shown separately. Each successive survey shows an increasing percentage of

Table 33

PREVIOUS MODE OF BART TRAVELERS

	Survey Year			
	1973	1974	1975	1976
East Bay BART Travel				
Bus	27%	24%	23%	18%
Automobile	56	50	46	48
Other Modes	3	2	2	2
Did Not Make Trip Before	14	24	29	32
Total	100%	100%	100%	100%
(Actual Number of Trips)	(24,900)	(40,700)	(37,600)	(40,700)
West Bay BART Travel				
Bus or Streetcar	n.a.	55%	52%	51%
Automobile	n.a.	30	26	26
Other Modes	n.a.	4	4	2
Did Not Make Trip Before	n.a.	11	18	21
Total		100%	100%	100%
(Actual Number of Trips)		(25,400)	(27,300)	(32,000)
Transbay BART Travel				
Bus	n.a.	54%	46%	30%
Automobile	n.a.	35	33	41
Did Not Make Trip Before	n.a.	11	21	29
Total		100%	100%	100%
(Actual Number of Trips)		(51,900)	(52,700)	(50,700)
Total for All BART Travel				
Bus or Streetcar	27%	44%	38%	31%
Automobile	56	39	36	39
Other Modes	3	2	2	2
Did Not Make Trip Before	14	15	24	28
Total	100%	100%	100%	100%
(Actual Number of Trips)	(24,900)	(118,000)	(117,600)	(123,400)

n.a. = not applicable (until November 1973, BART only provided East Bay service).

Automobile category includes motorcycle. See footnote on following page.

Sources: 1973, 1974, 1975, and 1976 BART Passenger Profile Surveys.
1974 BART Impact Program Transbay Travel Survey.

travelers who "did not make the trip before BART." Conversely, the percentage of BART riders who made the same trip before BART becomes smaller as the interval between the start date of BART service and the survey date increases.*

Changes in home and work locations account for most of the trips that travelers report they did not make previously. The 1976 BART passenger profile survey results show that 28% of respondents reported they did not make the trip before BART. Of these, 21% did not make the trip because they "did not live where they do now" or "did not work where they do now." The remaining 7% are trips not made before for other reasons, including "did not have convenient transportation available." Analysis of data from the 1976 passenger profile and other surveys suggests that between 5% and 10% of BART trips are "induced" by BART service itself; that is, they are trips that would probably not be made at all if BART were not available.

As the percentage of BART travelers who never made the trip before increases, estimating the hypothetical without-BART mode distribution of BART's ridership from the previous mode of travel distribution becomes

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*Comparisons of results among the five different surveys shown in Table 33 are complicated by the different ways in which the question about previous travel mode was asked. In the 1973, 1974, and 1975 passenger profile surveys, the question was "How did you make this type of trip prior to BART service?" The 1974 transbay travel survey question was similar. Some respondents may have interpreted this to mean prior to September 1972, when BART first began service on the Fremont Line. In the 1976 passenger profile survey, the question was "Did you ever make the trip you are now making before you used BART?"; if yes, "How?" Comparisons are also complicated by different sampling procedures and controls adopted in the surveys, and different methods used to weight the results to compensate for differential response rates. The 1976 BART passenger profile survey was the most carefully controlled.

more uncertain, because information is unavailable on the alternative mode of people who did not travel previously. However, taking into account this uncertainty, the results of the four surveys shown in Table 33 appear to be generally consistent. Considering only the estimates for East Bay travelers who made the trip before BART, about 30% of BART's ridership was drawn from buses, and about 70% from automobiles. In the West Bay, the picture is very different, with perhaps 65% of BART's ridership coming from buses and only 35% from automobiles.

The survey of transbay travel conducted immediately after BART transbay service began in 1974 shows that, for trips made before BART, about 60% were diverted from buses and 40% from automobiles. The more recent surveys suggest that, as time has passed, as buses competitive to BART have been cut back, and as traffic congestion on the Bay Bridge has built up, BART has drawn more transbay riders from automobiles than from buses. (Omitting those who did not travel previously, the alternative mode distribution of BART riders is shown in the 1976 survey as about 45% from buses and 55% from automobiles.)

In a hypothetical without-BART transportation system in which bus service levels, traffic congestion, and the relative costs of travel by bus and automobile are at their pre-BART levels, about 50% of current BART trips probably would be made by bus and 50% by automobile. In the East Bay the split would be approximately 30% bus, 70% automobile; in the West Bay it would be 65% bus, 35% automobile; and the transbay split would be 60% bus, 40% automobile.

Second Choice Mode of BART Travelers. Modal choices between BART and bus, and BART and automobile for the journey to work were analyzed from 1977 work travel survey data. In the following discussion, the usual (or first choice) mode is the one given in the questionnaire as the mode used most often in a typical week. The second choice mode is defined as the mode of getting to work that would be the second choice if the usual mode were not available.

Among daily work trips made by people whose usual mode is automobile, about 89% are typically made by automobile on a given day; that is, people whose usual mode is driving seldom use other means of getting to work. Of work trips made by people whose usual mode is bus, a rather smaller proportion, 81%, is typically made by bus on a given day; that is, a higher proportion of "usual" bus users sometimes travel to or from work by other modes (mostly automobile). This tendency is even more marked in BART's case. Of trips made by people whose usual mode is BART, typically only 65% are actually made by BART on a given day. The other 35% of trips are made by bus or automobile (about equally).

Table 34 shows the second choice mode for commuters whose first choice mode is BART according to (1) workplace (San Francisco CBD, Oakland CBD, non-CBD) and (2) travel area (West Bay, transbay, East Bay). Percentages given in the table are based on totals excluding trips for which no second choice is indicated.

CBD and Non-CBD Work Trips. Among all workers covered by the survey and specifying BART as their first choice mode, 59% give automobile as their second choice mode (51% drive alone, 8% carpool), and 36% give bus as their second choice mode. For travel to the San Francisco CBD, slightly fewer BART users (55%) give automobile as their second choice mode and correspondingly more (41%) give bus. This reflects the dense network of MUNI bus and streetcar lines from most areas of San Francisco to downtown, and the relatively high parking costs in the central area. Conversely, for trips to the Oakland CBD, a higher percentage (76%) specify automobile as their second choice mode, and a correspondingly smaller percentage (23%) specify bus. Among non-CBD trips (for which BART is selected as the first choice mode by a relatively small percentage of travelers), automobile is specified as the alternative by 49% of BART users and bus by 38%.

Table 34

ALTERNATIVE MODES FOR WORK TRIPS USUALLY MADE BY BART

	Work Trip Destination			
Second-Choice Mode	San Francisco CBD	Oakland CBD	Non-CBD	Total
Bus or Streetcar	41%	23%	37%	36%
Drive Alone or With Family	47	71	38	51
Carpool	8	5	11	8
Walk	2	1	6	2
Other	2	--	8	3
	100%	100%	100%	100%
Total Trips Represented[a]	23,800	12,900	12,100	48,800

	Travel Area			
	Trips Within West Bay	Transbay Trips	Trips Within East Bay	Total
Bus or Streetcar	51%	36%	31%	38%
Drive Alone or With Family	35	51	52	47
Carpool	6	11	8	8
Walk	4	--	5	3
Other	4	2	4	4
	100%	100%	100%	100%
Total Trips Represented[b]	10,300	8,400	16,300	35,000

a. All BART trips in the work travel survey, excluding trips for which no second-choice mode was specified.

b. BART trips in the work travel survey from origins within the primary BART service area, excluding trips for which no second choice mode was specified.

Source: BART Impact Program, 1977 Work Travel Survey.

West Bay, Transbay, and East Bay Work Trips. In the West Bay, bus is the principal alternative mode to BART; among those commuters whose first choice is BART, 51% specify bus as their second choice and 41% specify automobile. In the East Bay, the reverse is true; among those whose first choice mode is BART, 31% specify bus as their second choice and 60% specify automobile. For transbay travel, 36% specify bus as the alternative and 62% specify automobile.

The percentages given in Table 34 may be taken as estimates of the modes that current BART riders would most likely use if BART were not available, given current bus service levels, highway traffic congestion, and other transportation costs. Note that this without-BART alternative transportation system is different from the without-BART alternative implied by the previous mode analysis given in the preceding section (where pre-BART transportation service levels are implicit).

The without-BART mode distributions given in Table 34 are appropriate for analysis of the reasons underlying commuters' choice between BART and the (current) alternative bus and automobile modes (as was summarized in Chapter IV). However, as discussed in Chapter I, the without-BART transportation system underlying the BART Impact Program's analyses is similar to that operating before BART began service. Consequently, the appropriate estimates of without-BART mode distribution for analysis of BART's impacts on travel patterns (as given in Chapters VII and VIII) are those derived from the previous mode analysis.

Conclusions

BART's share of travel in the San Francisco Bay Area depends very heavily on the way in which the relevant travel market is defined, ranging from well under 1% of trips for some purposes (measured relative to all trips made areawide) to well over 50% of work trips in some corridors (measured relative to trips which commuters consider they could possibly make by BART).

Looking at the Bay Area as a whole, BART's share of travel is small: somewhere between 2% and 3% of all trips made by residents of the greater BART service area are made on BART, and about 5% of areawide trips to and from work are made on BART. When this small share is combined with the relatively high percentage of BART trips which, without BART, would probably be made by bus, an even smaller impact on areawide modal split is revealed, even among work trips. Comparing U.S. Census journey-to-work data in the three BART District counties for 1970 and 1975 suggests a 2% overall change in the work trip modal split between automobile and transit (from 80% automobile, 20% transit pre-BART to 78% automobile, 22% transit post-BART); and some part of this change may be attributable to factors other than BART.

However, this small areawide impact is as might reasonably be expected. The BART System, with only 71 miles of track, should not be expected to have major impacts on the overall travel patterns of an urbanized area of 330 square miles and served by many hundreds of miles of freeways and bus routes. Nor should BART be expected to serve effectively the travel desires of all population groups in an area of 2.6 million people; some population groups and travel patterns are inevitably served better than others.

Although its share of trips is small areawide BART has captured a significant share in a few well-defined travel corridors and for certain kinds of trips. These are largely the long-distance journeys to work in the central business districts of San Francisco and Oakland, particularly transbay trips to San Francisco, which are the trips the System was primarily intended to serve: in the San Francisco-Oakland Bay Bridge corridor, BART is used for 19% of all weekday trips made for all purposes and 21% of work trips. The modal split between automobile and transit modes (for all purposes) changed from 76% automobile, 24% transit pre-BART to 68% automobile, 32% transit afterwards.

VII. IMPACTS ON BUS RIDERSHIP AND SERVICE

BART's impacts on the other major transit systems in the Bay Area, particularly on the MUNI bus and other transit services in San Francisco and the AC Transit East Bay and transbay bus services, are discussed in this chapter.* A description of the services provided by these and other Bay Area transit operators is given in Chapter III.

Areawide Transit Ridership

Weekday ridership on MUNI, AC Transit, and BART is shown in Figure 13. In October 1976, average weekday ridership was about 345,000 passenger trips on all services of MUNI, 210,000 on all services of AC Transit, and 132,000 on BART.** As shown in Table 28, Chapter VI, BART carries 18% of all transit trips made by people living in the greater BART service area. Thus, BART accounts for a significant share of total areawide transit ridership. However, no BART impacts on MUNI and AC Transit total ridership are obvious from Figure 13.

One reason for this absence of obvious BART impacts is that the data shown in Figure 13 include double counting (that is, a single trip using both AC Transit and BART is counted as a trip on each). Growth in bus ridership for reasons unrelated to BART may also mask BART's impacts. However, the principal reason for the apparent lack of BART impacts in aggregate is that the loss of bus ridership on services parallel to BART has been offset by the use of the bus to get to and from BART stations, as discussed in the following sections.

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*A more detailed analysis of BART's impacts on bus ridership and service, documenting the results summarized in this chapter, is given in Reference 10, pp. 37-71.

**Among Bay Area transit systems not shown in Figure 13, Golden Gate Transit carried about 30,000 passenger trips per weekday in October 1976, SamTrans carried about 20,000 (on all its services, including those outside the greater BART service area), and Greyhound carried about 2,000 (just on its Concord corridor services).

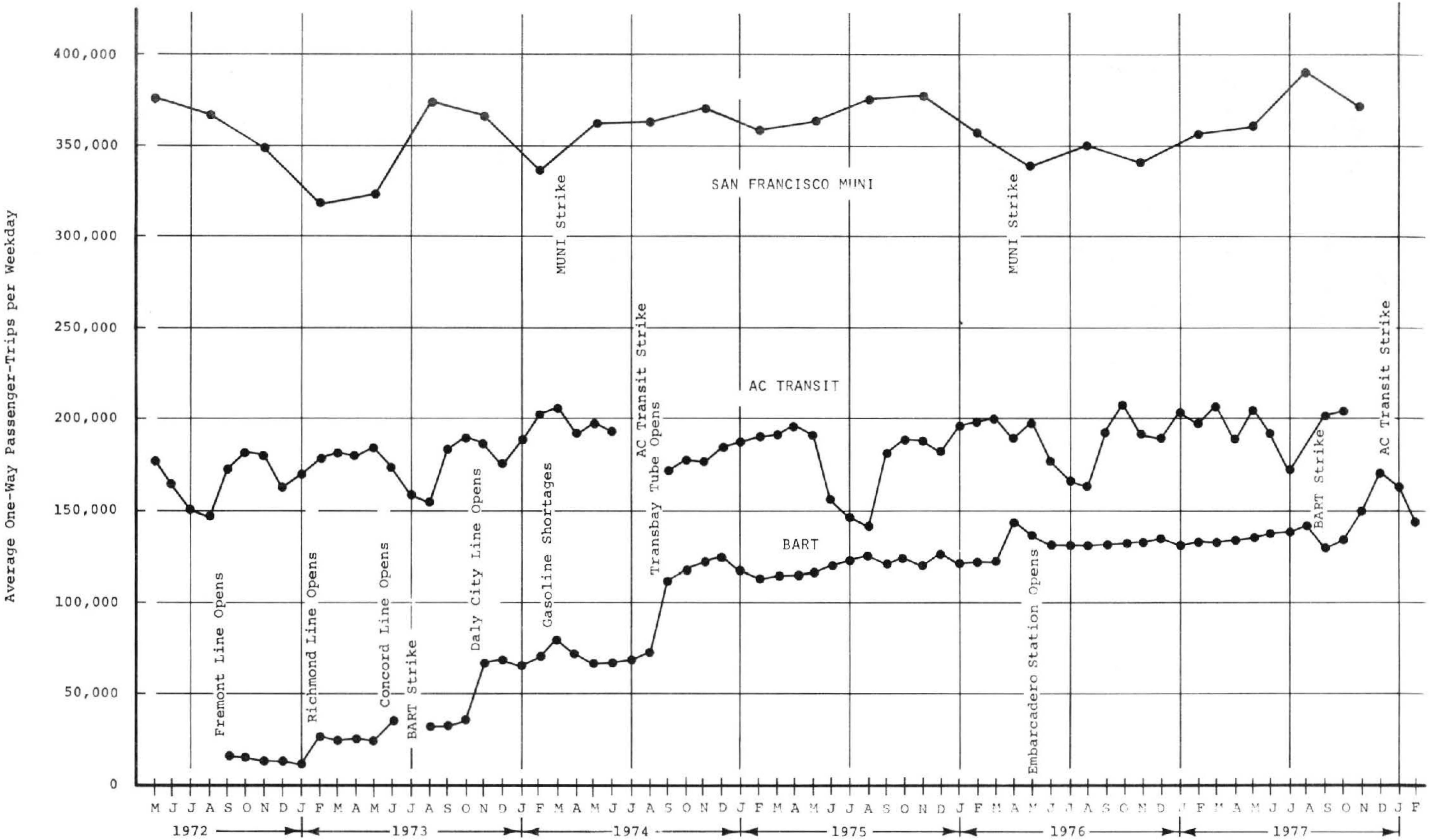

FIGURE 13

WEEKDAY RIDERSHIP ON MUNI, AC TRANSIT, AND BART MAY 1972 - FEBRUARY 1978

Source:
- San Francisco MUNI, Quarterly Patronage Reports.
- AC Transit District, Daily Passenger Counts.
- BART District Office of Research, Monthly Patronage Reports.

San Francisco Bus Ridership and Service

San Francisco MUNI Ridership.* According to 1976 BART passenger profile survey results, of the 36,900 West Bay trips made on BART (October 1976), 62% or 22,800 trips in total, would be made on the MUNI system if BART were not available. These 22,800 trips represent about 7% of MUNI's total October 1976 weekday ridership of 345,000.

This diversion of trips from parallel MUNI bus services to BART is offset by trips now made on MUNI to get to or from West Bay BART stations. Estimates of the number of trips made to and from BART in San Francisco according to the mode of travel used before BART are presented in Table 35. Two groups of BART trips are shown: trips made entirely within the West Bay (which have two access trips in the West Bay associated with every BART trip) and transbay BART trips (which have a San Francisco access trip at only one end of the BART trip).

Numbers in the table marked with a solid circle represent completely new access trips on MUNI, totaling 8,800 trips daily. Numbers marked with a hollow circle represent estimates of access trips on MUNI that substitute for "line-haul" trips previously made on MUNI. These total 12,700 trips daily. The number marked with a solid square represents a loss of access trips on MUNI (4,500 trips). The table thus portrays a net gain of 17,000 access trips daily by travelers using MUNI to get to or from BART (8,800 plus 12,700 minus 4,500), which offset the estimated 22,800 line-haul trips that the MUNI system lost.

The access trips are generally shorter than the line-haul trips, are less downtown-oriented, and (because of the 50% BART-MUNI transfer discount) produce a lower average fare box revenue per trip. However, this fare box revenue loss is made up by an operating subsidy. Thus, the two trip estimates are not strictly comparable, but taking the two estimates

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*Some of the trips described in this section as being made by bus may actually be on the streetcar, cablecar, or trolley bus services operated by MUNI.

Table 35

USE OF MUNI TO GET TO AND FROM BART

	Number of Trips to and from BART Using: MUNI Bus or Streetcar	Number of Trips to and from BART Using: Walking, Automobile, or Other Mode	Total Access Trips
Trips Within San Francisco			
New trips	400 ●	2,200	2,600
Previously used MUNI bus or streetcar	8,100 ○	37,500	45,600
Previously walked, used automobile or other mode	3,500 ●	22,100	25,600
Subtotal, trips within San Francisco	12,000	61,800	73,800
Transbay Trips			
New trips	800 ●	3,400	4,200
Previously used transbay bus and used MUNI to get to or from transbay bus terminal	4,600 ○	4,500 ■	9,100
Previously used transbay bus and walked or used some other mode to get to or from bus terminal	200 ●	18,500	18,700
Previously used automobile or some other mode	3,900 ●	17,200	21,100
Subtotal, transbay trips	9,500	43,600	53,100
Total trips to and from BART	21,500	105,400	126,900

● : Access trips representing a gain to MUNI.
○ : Access trips substituting for pre-BART MUNI trips.
■ : Access trips representing a loss to MUNI.

Note: All numbers in the table are daily access trips to and from BART stations, with a single origin-to-destination trip on BART including two access trips, one from the origin to BART, and one from BART to the destination. Details of the analysis underlying estimates in the table are given in Reference 10, p. 46.

together gives a net loss of 5,800 trips daily on the MUNI system. This represents less than 2% of the current total weekday ridership on the entire MUNI system. Significant net changes in ridership have apparently occurred only on a few lines paralleling the BART line from Daly City to downtown San Francisco.

San Francisco MUNI Service. A comprehensive study of coordinating the services of MUNI and BART was conducted before the start of BART service on the Daly City Line (Reference 22). The recommendations were keyed to four phases of BART service, of which Phase I (BART begins service in San Francisco) and Phase II (6-minute BART headways and 50% BART-MUNI transfer discount) have so far been achieved.

The Phase I recommendations, which mostly extended MUNI lines to BART stations, were all implemented. The Phase II recommendations for improved feeder bus coverage were also mostly implemented. However, the more extensive Phase II recommendations for downgrading bus services paralleling BART have generally not been implemented at the level recommended; in many cases, proposals for substantial service reductions were prevented or delayed by public protest.

The principal MUNI bus lines paralleling BART are shown in Figure 14. Although BART service resulted in substantial drops in patronage, neither the 14L nor 26X lines were eliminated, and service reductions on 14GL, 14X, and 17X lines have all been less than recommended.* The allowed cutbacks in service were not implemented until a full three years after BART Daly City Line service began.

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*An "L" suffix indicates a limited-stop line, an "X" suffix indicates an express line.

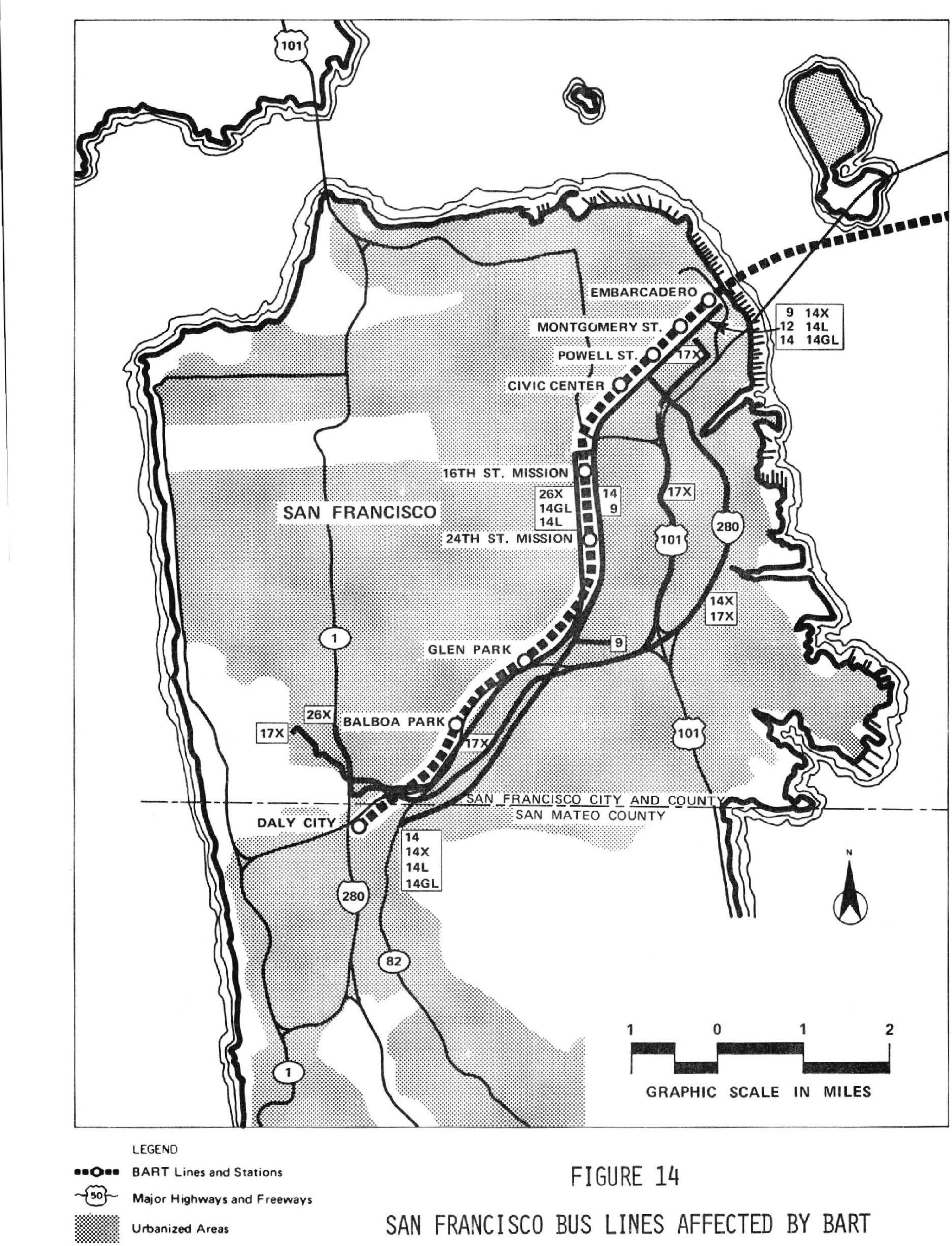

FIGURE 14

SAN FRANCISCO BUS LINES AFFECTED BY BART

East Bay Bus Ridership and Service

East Bay AC Transit Ridership. When BART service started in 1972, AC Transit provided bus service in the East Bay to an 11-city area west of the Berkeley and San Leandro Hills and stretching from Richmond and San Pablo in the north to Hayward in the south. Since then, AC Transit's service area has increased substantially: service began in Fremont and Newark in 1974 and in areas of central Contra Costa County (Concord, Pleasant Hill, and Orinda) in 1975 (see Figure 8, Chapter III). In 1974, AC Transit also began operating the "BART Express" bus lines to more distant areas of Alameda and Contra Costa Counties (see Figure 9).

Historical Increases in Ridership. Most of AC Transit's East Bay bus lines connect with the BART System at some point, and significant changes in ridership patterns have taken place since BART's introduction. However, BART's net impacts are difficult to establish from aggregate ridership data, given the large month-to-month fluctuations caused by seasonal and other influences. In the seven months from February through August 1972 (before BART began service), East Bay bus ridership averaged 117,900 passenger trips per weekday. In the seven months from February through August 1973 (after BART service was operating on the Fremont and Richmond BART Lines), East Bay bus ridership averaged 116,200 trips per weekday. The drop of 1,700 trips per weekday, representing less than 2% of the total, suggests that, as in the West Bay, diversion from bus to BART has been offset by the use of AC Transit buses to get to and from BART.

Since 1973, East Bay bus ridership appears to have risen considerably. In the seven months from February through August 1976, ridership on the lines included in the 1972 estimate averaged 134,500 trips per weekday, 15% higher than in 1972. In addition, significant ridership increases have also been recorded on AC Transit's new services. In October 1976, ridership on the Fremont and Newark services averaged 4,000 trips per weekday; on the Concord, Pleasant Hill, and Orinda services, 3,000; and on the BART Express Bus services, 4,100. Since most of these bus lines are oriented toward serving BART stations, many of the passenger trips are made by people using AC Transit buses to get to and from BART. The heavy use of AC Transit buses by people to get to and from BART stations is also illustrated by the number of transfers recorded from BART to bus. In October 1976, these transfers averaged 14,500 per weekday.

BART Impacts on Net Ridership. Based on 1976 BART passenger profile survey results and October 1976 BART ridership levels, it is estimated that, if BART were not available, 23% of the 41,600 daily trips made on BART within the East Bay, or 9,700 trips in total, would be made on AC Transit buses. These 9,700 trips represent about 6% of total ridership on AC Transit's East Bay services (153,000 trips per weekday).

Estimates of the number of trips made by travelers who use AC Transit buses to get to or from BART stations are given in Table 36. The distribution of current access modes to and from BART is cross-tabulated in the table by the pre-BART travel mode. Two groups of trips are shown: (1) trips made entirely within the East Bay (which have an access trip portion at both origin and destination) and (2) transbay trips (which have an access portion in the East Bay at only one end of the trip).

Numbers in the table marked with a solid circle are estimates of gains in daily access trips for the AC Transit system. These trips (totaling 21,900) represent estimates of entirely new bus trips. Numbers marked with a hollow circle (totaling 7,300) represent access bus trips that substitute for previous "line-haul" bus trips. The number marked with a square, 2,700 trips, represents a loss of bus access trips on the AC Transit system. (These are trips by travelers who previously transferred between East Bay local lines and transbay lines.)

The analysis summarized in Table 36 indicates that BART has had the net effect of adding 26,500 access trips daily to AC Transit's East Bay

Table 36

USE OF EAST BAY AC TRANSIT TO GET TO AND FROM BART

	Number of Trips to and from BART Using: AC Transit Bus	Number of Trips to and from BART Using: Walking, Automobile, or Other Mode	Total Access Trips
Trips Within the East Bay			
New trips	1,700 ●	5,200	6,900
Previously used AC Transit bus	6,600 ○	12,800	19,400
Previously walked, used automobile or other mode	12,000 ●	44,900	56,900
Subtotal, trips within East Bay	20,300	62,900	83,200
Transbay Trips			
New trips	700 ●	3,500	4,200
Previously used transbay bus and transferred to or from another AC Transit bus	700 ○	2,700 ■	3,400
Previously used transbay bus and walked or used some other access mode in the East Bay	4,800 ●	19,600	24,400
Previously used automobile or some other mode	2,700 ●	18,400	21,100
Subtotal, transbay trips	8,900	44,200	53,100
Total trips to and from BART	29,200	107,100	136,300

: Access trips representing a gain to AC Transit.
○ : Access trips substituting for pre-BART AC Transit.
: Access trips representing a loss to AC Transit.

Note: All numbers in the table are daily access trips to and from BART stations, with a single origin-to-destination trip on BART including two access trips, one from the origin to BART, and one from BART to the destination. Details of the analyses underlying estimates in the table are given in Reference 10, p. 59.

ridership, including those access trips which substitute for previous line-haul trips (21,900 plus 7,300 minus 2,700). The estimate of 26,500 access trips gained by the bus system clearly more than offsets the estimated 9,700 line-haul trips diverted from AC Transit to BART. Again, the access trips are generally shorter and generate a lower average fare revenue per trip, both because AC Transit fares are graduated with distance and because of the 50% BART-AC Transit transfer discount fare.

East Bay AC Transit Service. A specific plan for coordinating AC Transit and BART services was not drawn up before East Bay BART service began (as was the case with MUNI in San Francisco). However, considerable effort has been expended in coordinating AC Transit bus services and BART, including establishing an AC Transit/BART Coordination Project. This joint effort by the Metropolitan Transportation Commission, the AC Transit District, and the BART District developed analysis procedures and a series of general recommendations for implementing and improving coordinated transit services (Reference 23).

As was the case in San Francisco, several service adjustments were made on bus lines to provide or improve feeder service to BART. However, very few significant reductions in East Bay bus service have resulted from BART's introduction. By and large, this reflects the pattern of demand on the various lines.

Of all AC Transit lines, only Line 30 from Hayward to Oakland has been eliminated completely to date, and service has been significantly reduced only on the following: Line 32 from Hayward and San Leandro to Oakland (where complete elimination of the line was prevented by public protest) and Lines 31 and 33 between Richmond and Oakland. No significant service cutbacks occurred on Lines 41, 43, or 72 (between Richmond and Oakland) or Lines 80, 81, or 82 (between Hayward and Oakland), although these lines apparently provide parallel service to BART.

Transbay Bus Ridership and Service

Transbay Bus Ridership. BART's greatest impacts on bus ridership have been in the San Francisco-Oakland Bay Bridge corridor. In the first three months of 1974, average weekday ridership on AC Transit's transbay lines (including trips made on these lines entirely within the East Bay) was 63,000 trips per day. In the first three months of 1975, following the start of transbay BART service, ridership on transbay bus lines fell to 44,200 trips per day; a drop of 18,800 trips or 30%. In the first three months of 1976, ridership had risen slightly to an average of 45,200 trips per weekday.

An even sharper drop occurred in ridership on Greyhound's transbay commuter services from the Concord-Walnut Creek area of Contra Costa County after the start of transbay BART service in September 1974. In the first three months of 1974, average weekday ridership on Greyhound buses was 12,000 trips per day; in the same three months of 1975, ridership averaged 3,400 trips per day, a loss of 8,600 trips or 72%. By the first three months of 1976, average weekday Greyhound ridership had dropped to 1,800 trips per day.

The losses of ridership on both AC Transit and Greyhound transbay lines amount to a total drop of 27,400 trips per weekday, or 13,700 trips per day in each direction. These figures are for total trips on transbay bus lines, not all of which actually cross the Bay. However, a trend analysis of actual transbay bus passenger trips (shown in Figure 21, Chapter VIII) gives an estimated reduction of 13,900 daily passenger trips, almost exactly the same result. (Thus, the loss in ridership on AC Transit's transbay lines was indeed accounted for by people traveling across the Bay, and not on transbay lines within the East Bay.) In the case of transbay bus services, the loss of line-haul ridership to BART has not been offset by any significant use of transbay buses to get to and from BART stations.

Ridership on AC Transit Transbay Lines. Comparing the average weekday ridership on individual AC Transit transbay lines for September 1974 (immediately before transbay BART) with the ridership for October 1974 (immediately after) shows a combined drop of 7,900 trips per day on the 13 principal transbay bus routes.* Almost all of this drop is accounted for by decreased ridership on just five lines: The A, C, E, F, and R Lines. As shown in Figure 15, these lines all parallel BART for much of their length. The L Line, which also approximately parallels BART (along the Richmond Line), shows no appreciable change in ridership between September and October 1974. Diversion of ridership from transbay buses to BART has probably been lower on the Richmond Line than on the Concord or Fremont Lines, in part because of the need to transfer between BART trains on Richmond-San Francisco trips (although the L Line bus from Richmond to downtown San Francisco via I-80 would show a travel time advantage for many people even over direct BART service).

AC Transit Transbay Bus Service. In response to reduced transbay bus ridership, service levels on AC Transit's transbay lines have been cut back, but no lines have been eliminated completely. From a base level of 35,800 weekday bus-miles scheduled on all transbay lines in December 1973, bus-miles decreased 3% to 34,900 by December 1974 (soon after the start of transbay BART service and before adjustments had been fully made in reaction to the drop in ridership) and 9% to 32,500 by December 1975. Generally, reductions in service levels on individual transbay bus lines reflect ridership losses.

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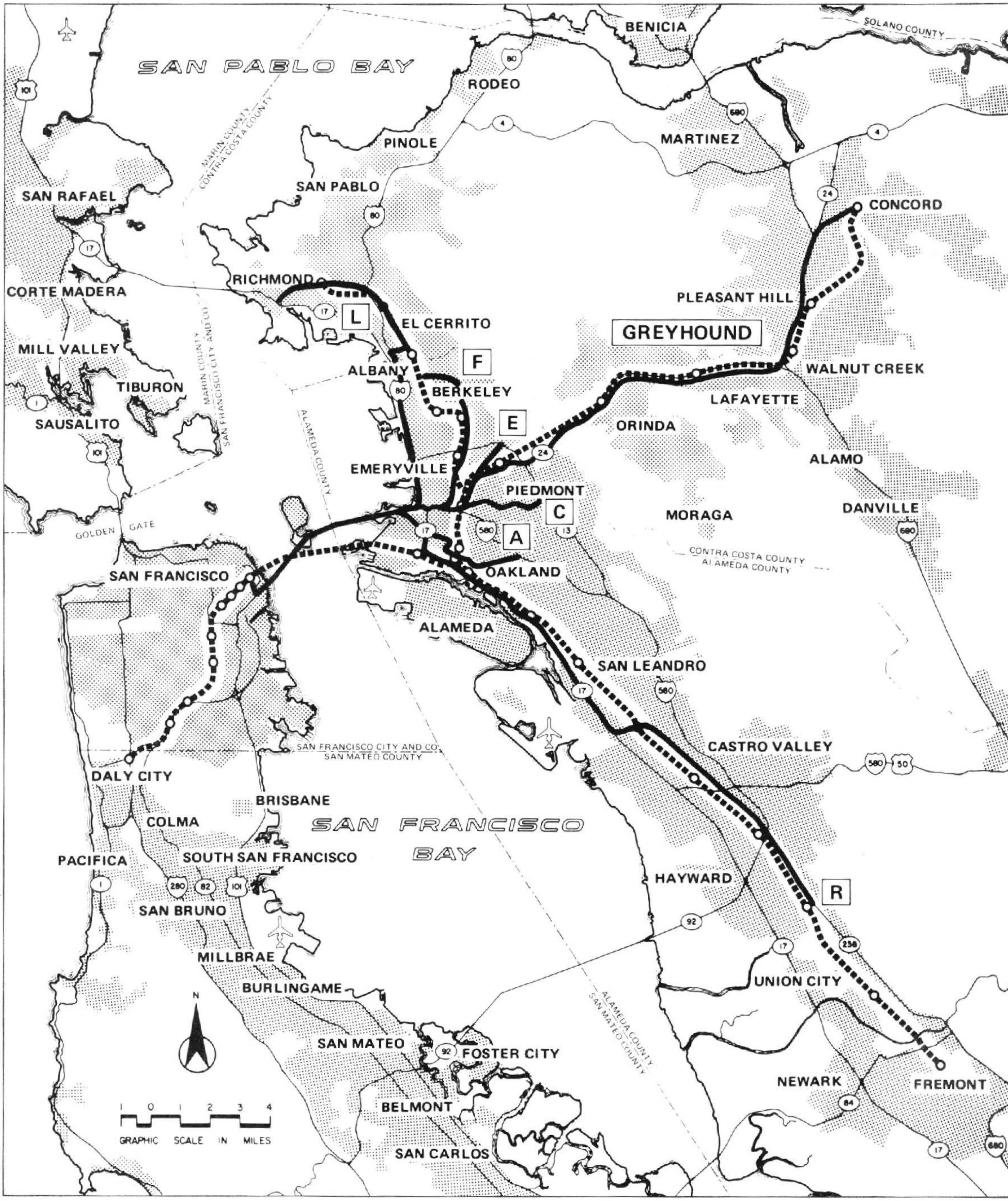
*Comparing the data for October 1973 (a year before transbay BART) with the data for October 1975 shows a much larger total reduction in transbay ridership (16,500 trips), but the distribution among lines is similar. Relatively low ridership levels in September 1974 reflect residual effects of an AC Transit strike in the two preceding months.



LEGEND

BART Lines and Stations

Major Highways and Freeways

Urbanized Areas

FIGURE 15

TRANSBAY BUS LINES AFFECTED BY BART

The transbay R Line paralleling the BART Fremont Line has experienced the greatest reduction in service, from 5-minute headways in the morning peak in December 1973 to 10-minute peak headways in December 1975. Service on the A Line has also been cut back significantly--from 10-minute peak headways in December 1973 to 20-minute peak headways in December 1975. However, as measured by scheduled bus-miles, service on the C, E, and F Lines has been cut back relatively little over the same period. On the C Line, morning peak-period average headways have increased from about 7 minutes to 8 minutes. On the E Line, the headways have increased from 10 minutes to 12 minutes, and on the F Line, they are unchanged at 5 minutes.

Greyhound Transbay Bus Service. Corresponding to the diversion of large numbers of trips to BART's Concord Line service, Greyhound transbay commuter bus services have been reduced drastically. In March 1974, when Greyhound carried 12,200 trips per day on its transbay lines, 242 vehicle-trips per day were made. By the end of 1976, with a ridership of about 1,700 trips per day, only 42 vehicle-trips per day were made. This drop in vehicle-trips represents more than an 80% reduction in service, approximately in proportion to the drop in ridership. The load factor (number of seats occupied) has fallen from about 50 in 1974 to about 40 currently. Greyhound has been granted permission to discontinue all off-peak weekday service in the Concord corridor since transbay BART service began, and has filed a request with the California State Public Utilities Commission to discontinue commuter service also.

Conclusions

Viewed relative to MUNI and AC Transit's total services and ridership, BART's net impacts have been small. Changes in the services provided by MUNI and AC Transit reflect BART's offsetting influences on the demand for parallel and feeder services. Improved feeder bus service has been provided by rerouting and increasing service on several MUNI lines.

Generally, however, bus services paralleling BART have not been downgraded to the degree some planners proposed. No MUNI line has been discontinued as a result of BART. Similarly, in the East Bay, AC Transit has introduced new bus lines and rerouted or extended existing lines to improve feeder service to BART. But on only a handful of East Bay lines paralleling BART has bus service been reduced, and, to date, on only one line has service been discontinued altogether. Thus, the start of BART service has not caused major disruptions to established bus operations in the Bay Area.

In some cases, proposals for service reductions were prevented or delayed by public protest. In other cases, the lower-than-expected cutbacks stem from the slow response of the bus system managers to changes in demand. For the most part, however, the level of service cutbacks simply reflects the reduced level of demand. Although BART effectively offers a parallel service to some bus lines, many people continue to use the bus because the bus offers faster, cheaper, or more reliable service for their journeys. Bus service changes also reflect BART's offsetting influences on the demand for parallel and feeder services. Many bus lines serve both riders who use the service as an alternative line-haul mode to BART and those who use the bus as a means of getting to and from BART stations.

In the Bay Area, no single authority is empowered to require cutbacks in bus services that apparently duplicate BART, or to direct any other change such as providing new feeder bus service. Changes in the services provided by MUNI, AC Transit, and other operators instead have resulted from more-or-less independent adjustments made by the various operators in response to changes in demand.* Consequently, the BART experience cannot directly address the advantages and disadvantages of pursuing a policy of "forced" rail-bus coordination, as might be proposed in another area with a different set of institutional constraints.

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*The history of relationships and negotiations between the various Bay Area transportation agencies and operators is documented and analyzed in Reference 19.

However, the analysis of BART impacts does show that, except in the few cases where the train exactly duplicates or improves bus service, many people continue to use the bus in preference to BART. An implication is that removal of apparently parallel bus service will, in many cases, remove the availability of the preferred travel alternative, and hence reduce the mobility, of significant numbers of travelers. In planning future systems, these losses in traveler mobility need to be weighed carefully against the cost savings that might be achieved. The overlapping nature of parallel and feeder demand further complicates the question of what level of bus service should be provided, because reducing service on apparently parallel routes (with the intention of increasing rail transit ridership) may deprive some travelers of their means of access to the rail station (thereby reducing rail transit ridership).

VIII. IMPACTS ON HIGHWAY TRAFFIC AND CONGESTION

BART's impacts on highway traffic volumes and congestion, and on total person-trips by private automobile and public transit combined, are analyzed in this chapter. The focus is on BART's impacts on traffic and travel volumes crossing the San Francisco-Oakland Bay Bridge; and an attempt is made to isolate BART's impacts from the many other factors influencing traffic and travel volumes.

In the first section, trends in highway traffic volumes on the San Francisco-Oakland Bay Bridge are analyzed relative to traffic trends on the three other major bridges crossing San Francico Bay. In the second section, a regression analysis of the different factors influencing traffic is described. In the third section, trends in total San Francisco-Oakland person-trips are analyzed by automobile, bus, and BART combined. In the fourth section, BART's impacts on Bay Bridge traffic congestion, as measured by travel times and delay, are described. Finally, BART's impacts on travel through the Caldecott Tunnel (paralleling the BART Concord Line) are assessed.* Figure 10 in Chapter III shows the location of the bridges and tunnel analyzed.

Trends in Traffic Volumes on Bridges Crossing San Francisco Bay

The four major bridges across San Francisco Bay are the San Francisco-Oakland Bay Bridge, the Golden Gate Bridge, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge.

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*A more complete analysis of BART's impacts on highway traffic volumes and congestion, and documentation of results summarized in this chapter, is given in Reference 10, pp. 73-145.

The San Francisco-Oakland Bay Bridge (generally known simply as the Bay Bridge) is the most important bridge as far as BART impacts are concerned. Typically, over 95,000 vehicles per day travel in each direction. BART service through the Transbay Tube parallel to the Bay Bridge was promoted and widely expected to have major impacts on this traffic volume.

The Golden Gate Bridge connects San Francisco to the residential areas of Marin County and, like the Bay Bridge, carries high volumes of commuter traffic to and from the City. Often, over 50,000 vehicles per day cross the bridge in each direction. Since there is no reason to suppose that BART has affected traffic volumes on the Golden Gate Bridge, it is a logical control for purposes of comparison in this section, even though other changes have occurred in the Golden Gate Corridor, including improved bus service, carpool incentives, and changes in tolls, that affect its use as a control.

The San Mateo-Hayward Bridge and the Richmond-San Rafael Bridge carry only about 15,000 and 10,000 vehicles per day in each direction, respectively. Nevertheless, comparing them with the Bay Bridge is useful because (1) the BART Fremont Line is a possible alternative to the San Mateo-Hayward Bridge for some travel from southern Alameda County to San Francisco, and (2) traffic on the Richmond-San Rafael Bridge is essentially unaffected by BART, making it another control site.

Long-Term Bridge Traffic Trends. Traffic volumes on all four bridges have for several years displayed regular (and marked) seasonal variations from month to month within the year and a steady underlying straight-line growth from year to year. At least this was the case prior to 1974 when gasoline shortages, the start of transbay BART service, and possibly other factors disrupted the established trends.

On the San Francisco-Oakland Bay Bridge, the linear trend for the 4 years from October 1969 to September 1973 shows an annual rate of increase of 1,800 vehicles per midweek day. This is an annual increase of 2.0% of the mean traffic volume for the whole period. On the Golden Gate Bridge, the corresponding increase was 1,100 vehicles per day, an annual increase of 2.4% of the mean traffic volume over the 4-year period. Traffic on the San Mateo-Hayward and Richmond-San Rafael Bridges also increased steadily over the period, but at much higher percentage rates. On the San Mateo-Hayward Bridge, the corresponding increase was 900 vehicles per day (6.0% of the mean), and on the Richmond-San Rafael Bridge, it was about 800 vehicles per day (8.4% of the mean).

All four bridges display similar recurrent seasonal variations in traffic with volumes typically high in the summer, low in winter, and close to the average in the spring and fall months of April, May, September, and October.

Comparison of Actual and Projected Traffic Volumes. An assumed continuation of these linear trends and month-to-month seasonal fluctuations form the without-BART alternative against which BART impacts are assessed in this chapter. The historical trend and seasonal patterns are projected for the 3-year period, October 1973 to October 1976. These projections represent "what might have been" had the introduction of BART, the gasoline crisis, and other factors not disrupted travel patterns. Differences between actual traffic volumes and the values projected by the regression model must be explained by factors other than trend and seasonal influences.

Figures 16, 17, 18, and 19 show actual and projected traffic volumes for the period from January 1972 through October 1976 for the

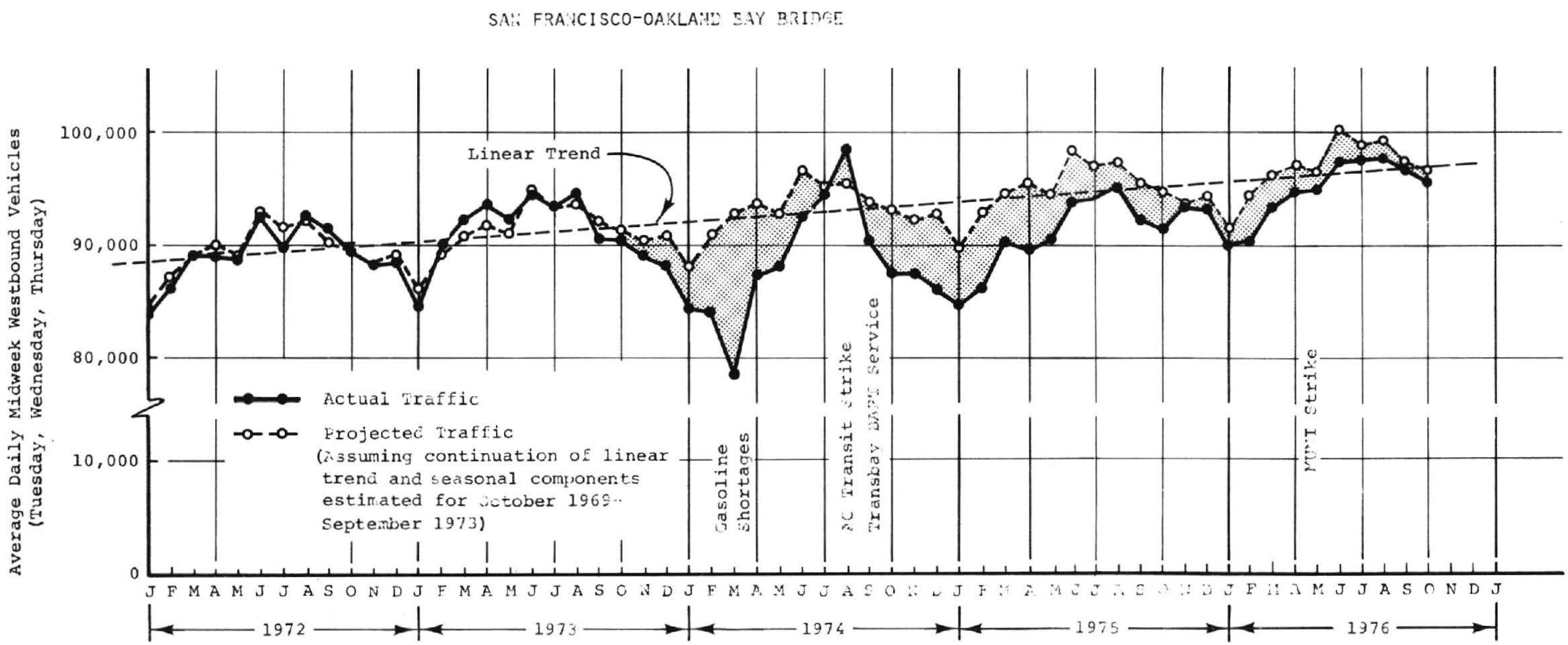

FIGURE 16

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- **CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.**
- **Peat, Marwick, Mitchell & Co. Analysis.**

GOLDEN GATE BRIDGE

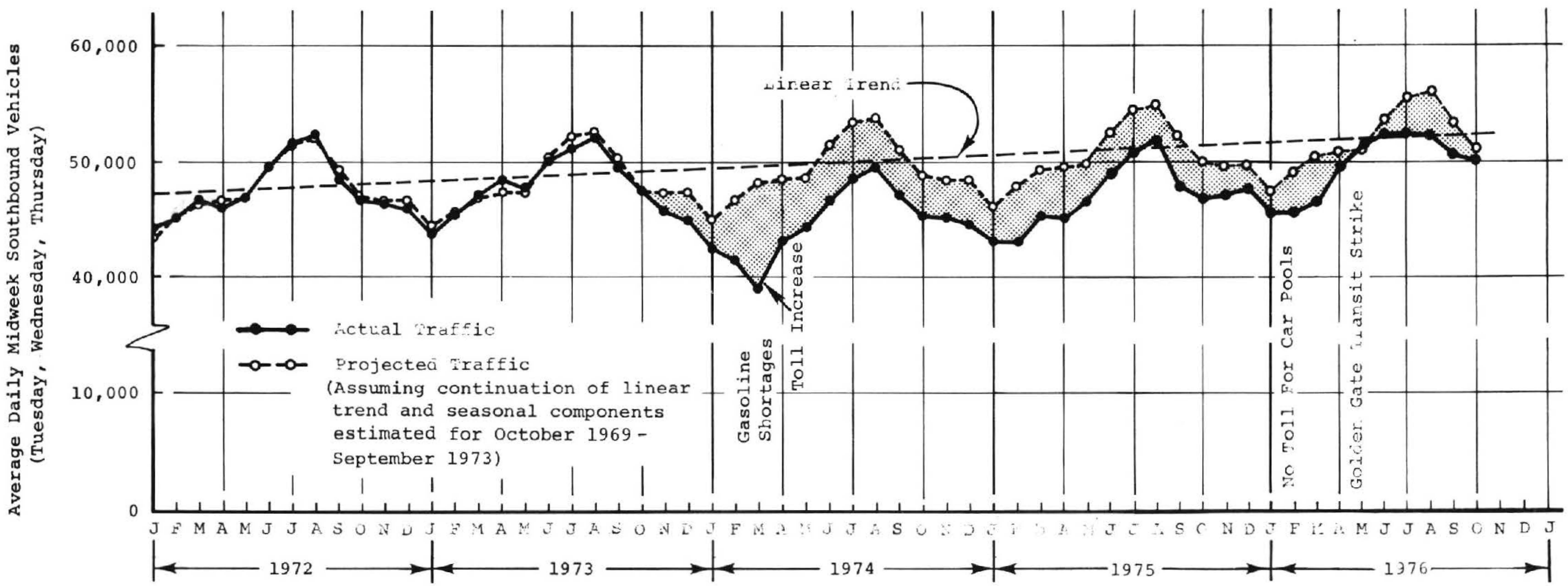

FIGURE 17

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE GOLDEN GATE BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- Golden Gate Bridge Highway and Transportation District, Summary Vehicle Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

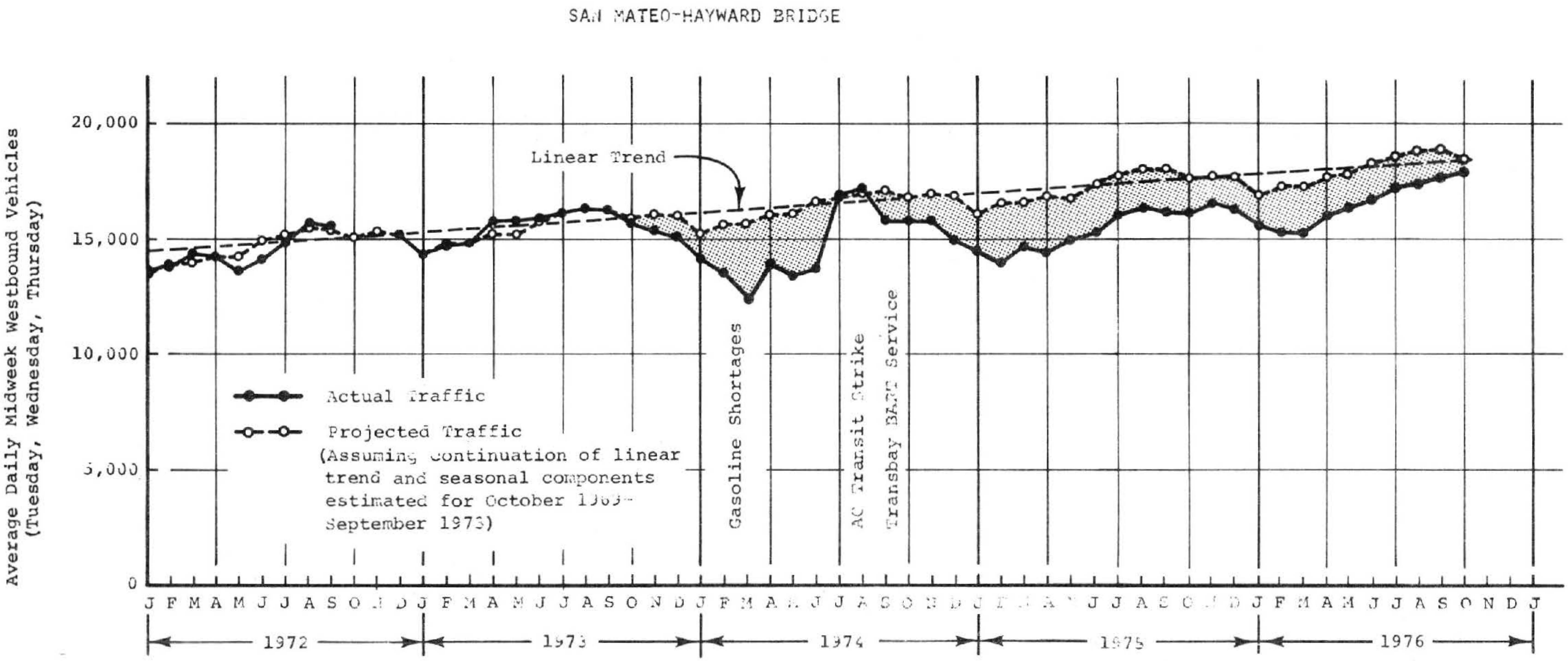

FIGURE 18

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE SAN MATEO-HAYWARD BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.
- Peat, Marwick, Mitchell & Co. Analysis.

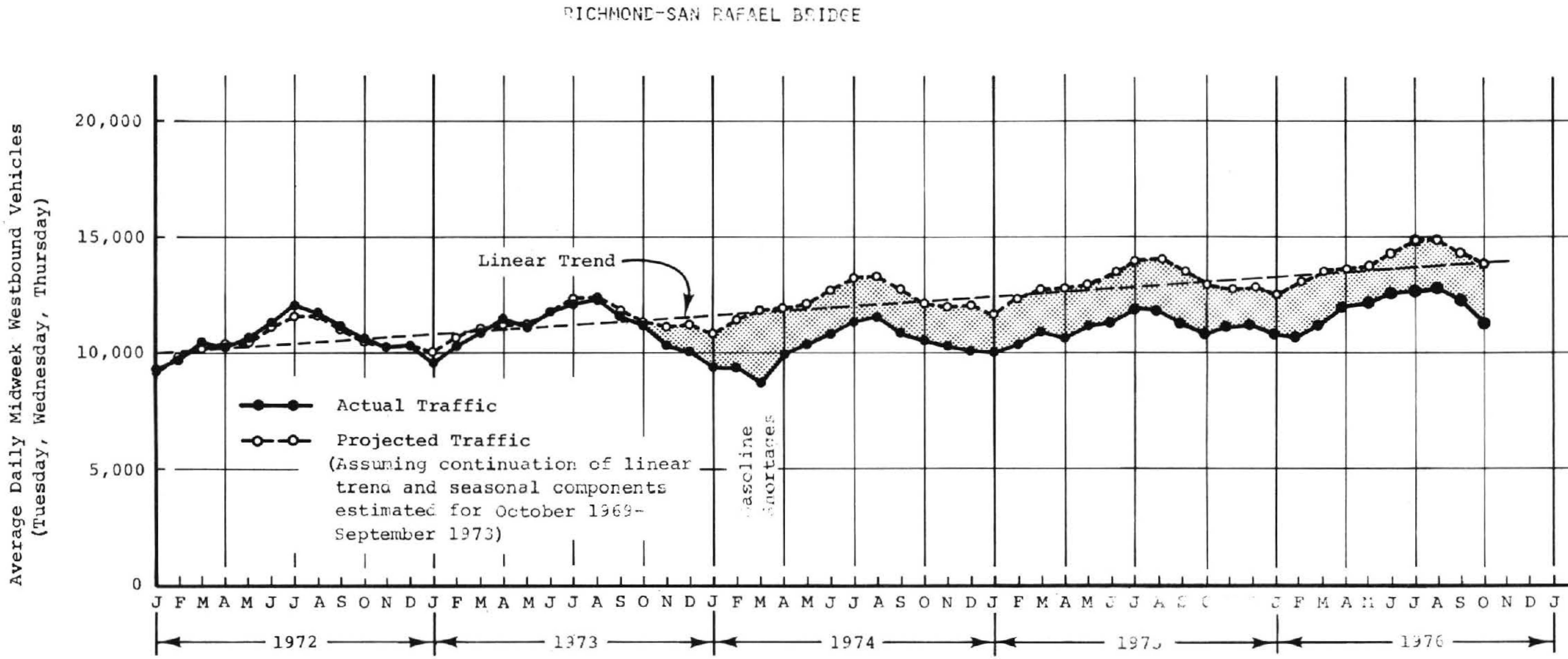

FIGURE 19

ACTUAL AND PROJECTED MIDWEEK TRAFFIC ON THE RICHMOND-SAN RAFAEL BRIDGE, JANUARY 1972 - OCTOBER 1976

Sources:
- **CALTRANS Toll Bridge Administration, Daily Totalizer Volume Counts.**
- **Peat, Marwick, Mitchell & Co. Analysis.**

San Francisco-Oakland Bay Bridge, the Golden Gate Bridge, the San Mateo-Hayward Bridge, and the Richmond-San Rafael Bridge, respectively. The differences between actual and projected traffic volumes from October 1973 onward are emphasized as shaded areas. These shaded areas represent the unexplained "shortfall" in traffic volumes. (Note that Figures 16 and 17 are drawn to a smaller vertical scale than Figures 18 and 19).

Factors Influencing Traffic Trends. Changes in traffic volumes are determined by many factors. Underlying trends are determined by the growth of the urban area, its population, economy, and automobile ownership and usage. Automobile usage was reduced by the gasoline shortages of early 1974 and probably by associated increases in gasoline prices. This resulted in modification of the underlying trends. The start of service on the BART System has changed highway traffic and bus ridership volumes, as have other events, including improvements in bus service, changes in the relative prices of travel by transit and automobile, transit strikes, and the opening of new highway facilities. Table 37 lists some of the more important events.

Figure 20 shows a time series of prices for regular gasoline in the Bay Area expressed in (1) current dollar prices and (2) constant (1967) dollar prices corrected for inflation using the Consumer Price Index. The price of gasoline in San Francisco in September 1972, when the first BART line opened, averaged $0.37 per gallon. In September 1974, when transbay BART began service, the average price was $0.58, an increase of 57% over the price 2 years before. Expressed relative to the prices of other consumer goods, the increase in gasoline prices has not been so dramatic, but is still high. The 1967 dollar price of a gallon of regular gasoline increased from $0.28 in September 1972 to $0.38 in September 1974 (a 36% increase).

Table 37

SELECTED EVENTS AFFECTING BAY AREA TRAVEL PATTERNS
1972-1977

1972	January	Route I-280 from Peninsula to San Francisco opened
	September	BART Fremont Line opened
1973	January	BART Richmond Line opened
	May	BART Concord Line opened
	July-August	BART strike closed system
	November	BART Daly City Line opened to San Francisco
	September-March 1974	Major gasoline price increases
1974	January-March	Gasoline shortages
	January	Maximum speed limit reduced to 55 mph
	March	Golden Gate Bridge toll increased to $0.75
	March	Metering system on Bay Bridge operational
	March	San Francisco workers strike closed MUNI
	July-August	AC Transit strike
	September	BART transbay service began
	December	BART extension "Express Bus" service began
1975	March	Bay Bridge toll eliminated for car pools
	November	BART fares increased
	November	BART evening service 8 p.m. to 12 midnight
1976	March-May	San Francisco workers strike closed MUNI
	April-June	Golden Gate Transit strike
	May	BART Embarcadero Station opened
1977	July	Bay Bridge and San Mateo Bridge tolls increased to $0.75
	August-September	BART Police Strike reduced BART service
	November	Golden Gate Bridge toll increased to $1.00
	November	Saturday BART service
	November-December	AC Transit strike (ended January 1978)

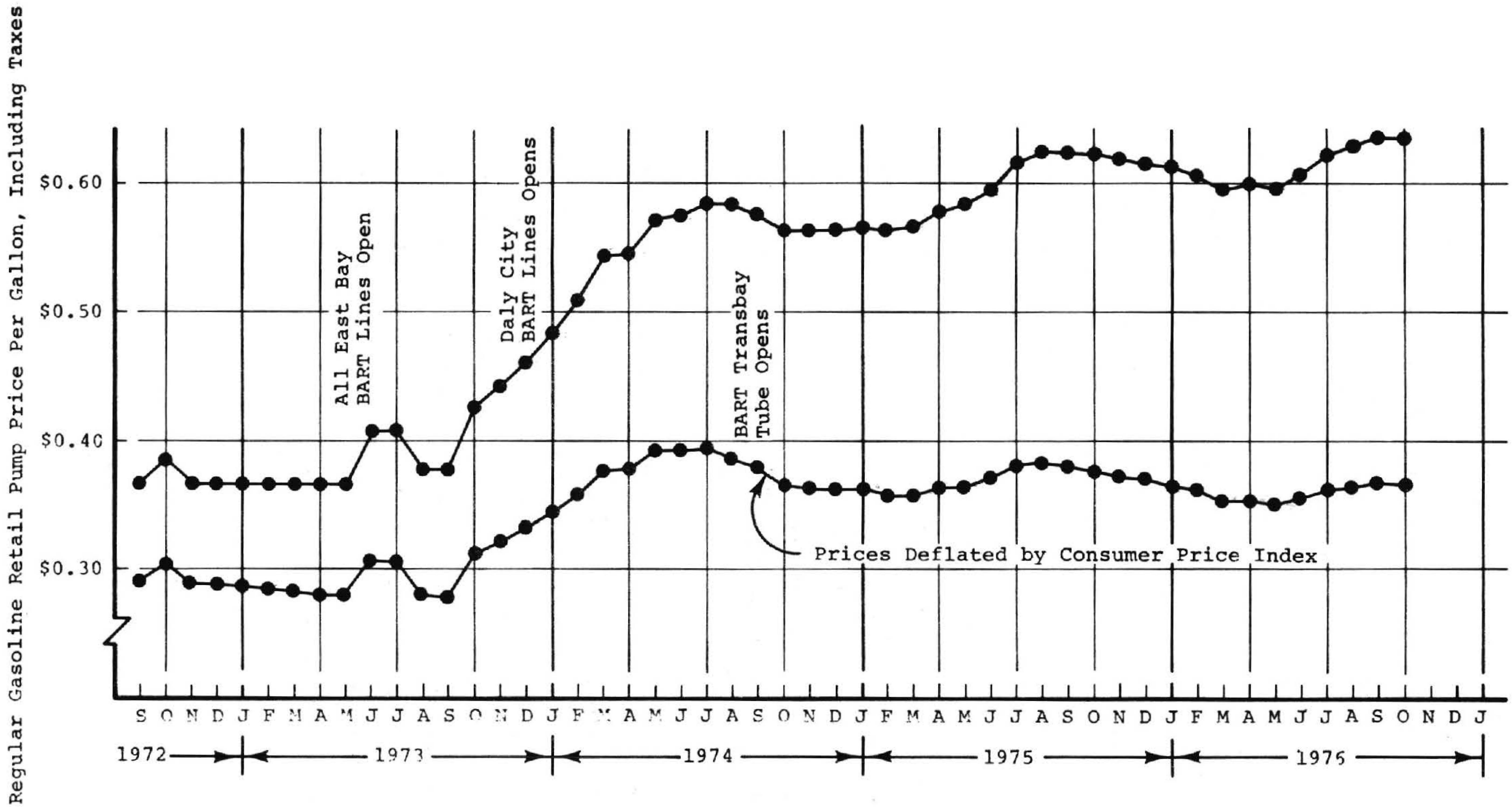

FIGURE 20

BAY AREA GASOLINE PRICES, SEPTEMBER 1972 - OCTOBER 1976

Sources:
- Platt's Oil Fact Book (San Francisco County to September 1973).
- U.S. Department of Labor (San Francisco-Oakland SMSA from October 1973).
- U.S. Department of Commerce, Survey of Current Business (Consumer Price Index).

San Francisco-Oakland Bay Bridge Traffic. The shaded area of Figure 16 clearly shows the effects of gasoline shortages in the spring of 1974 when actual traffic levels fell far below those projected. Traffic levels recovered when gasoline again became available in the early summer of 1974, but the cumulative effects of increased gasoline prices continued to depress actual traffic volumes below projected volumes in May and June. In July and August of 1974, the AC Transit strike caused Bay Bridge traffic to increase above the projected line. The difference between the projected and actual traffic volumes from September 1974 onward represents the combined effects of transbay BART service opening in mid-September, the continuation of higher gasoline prices, and all other factors. The relative influences of these various factors are discussed later.

The difference between actual and projected Bay Bridge traffic volumes appears to have decreased over the 2 years since transbay BART opened; that is, actual traffic volumes have "caught up" with the projected volumes. Average daily traffic in September 1976 was not much different from the level that might reasonably have been anticipated without BART.

The average 3,300-vehicle-per-day shortfall illustrated in Figure 16 for the entire 2-year period, October 1974 through September 1976 (representing the net decrease in traffic resulting from the combined effects of BART and other factors) is approximately twice the long-run annual growth of 1,800 vehicles per day. Thus, relative to the baseline defined by the trend-plus-seasonal projection, the net traffic-reducing effects of BART and all other factors (averaged over the 2 years since transbay BART service began) is equivalent to about 2 years' normal historical growth in Bay Bridge traffic.

Golden Gate Bridge Traffic. The pattern in Figure 17 is similar to that in Figure 16 with the important exceptions that traffic volumes on the Golden Gate Bridge were unaffected by the July-August 1974 AC Transit strike and have not been influenced by BART. The difference between the projected and actual traffic level, therefore, shows a much more regular pattern, reflecting the effects of the gasoline shortage, associated gasoline price increases, and the March 1974 toll increase from $0.50 to $0.75. From May 1974 on, the actual traffic levels closely follow those projected by the trend-plus-seasonal model, with the actual points displaced below the projected points by a nearly constant amount (except for April, May, and June 1976, when a Golden Gate Transit bus strike affected traffic levels). Excluding these 3 months, the average shortfall is 3,300 vehicles per day.

San Mateo-Hayward Bridge Traffic. Figure 18 shows the difference between projected and actual traffic levels on the San Mateo-Hayward Bridge. A pattern very similar to that of the Bay Bridge is apparent. The figure clearly shows (1) the effects of the gasoline shortages in early 1974, (2) the effects of the AC Transit strike in diverting traffic from the Bay Bridge to the San Mateo Bridge, and (3) the (presumed) continuing effects of increased gasoline prices. BART-related traffic reductions may also be reflected over the final 2 years shown in the figure. As with the Golden Gate Bridge, the shortfall below projected traffic volumes has been fairly constant from October 1974 to September 1976, averaging 1,700 vehicles per day.

Richmond-San Rafael Bridge Traffic. Figure 19 compares projected and actual traffic levels for the Richmond-San Rafael Bridge, showing a pattern very similar to that of the Golden Gate Bridge. As with the Golden Gate Bridge, neither the AC Transit strike nor BART has affected traffic levels; the difference between projected and actual levels represents only the effects of gasoline availability and price, and possibly other factors. Again, the shortfall below projected traffic volumes is more or less constant over the 2 years October 1974 through September 1976, averaging 1,900 vehicles per day.

Summary of Traffic Trend Analysis. Table 38 summarizes the trend analysis of average daily midweek traffic on the four bridges. The table shows (1) average daily midweek traffic volumes projected from the trend-plus-seasonal model for the 2-year period from October 1974 (immediately after the start of transbay BART service) through September 1976; (2) the average actual daily midweek traffic volume for the same 2 years; (3) the difference between the projected and actual volumes; (4) this difference expressed as a percentage of the projected level; and (5) the slope of the long-run trend in traffic growth (that is, the annual increase in average daily traffic from October 1969 to September 1973 expressed as a percentage of the average daily traffic over the 4 years); (6) the number of traffic lanes in each direction on the bridges; and (7) the average daily volumes divided by the number of lanes. Insofar as the number of lanes indicates bridge capacity, the latter figures form crude measures of the volume-to-capacity characteristics of the bridges.

The opening of transbay BART service was expected to have major impacts on the San Francisco-Oakland Bay Bridge. But in fact, the total reduction in average daily traffic on the Bay Bridge shown in Table 38 (3,300 vehicles per day) is the same as the reduction on the Golden Gate Bridge

Table 38

SUMMARY OF ACTUAL AND PROJECTED AVERAGE DAILY MIDWEEK BRIDGE TRAFFIC

	San Francisco-Oakland Bay Bridge	Golden Gate Bridge	San Mateo-Hayward Bridge	Richmond-San Rafael Bridge
Average Projected Daily Traffic[a] October 1974-September 1976	95,400	50,600	17,500	13,200
Average Actual Daily Traffic October 1974-September 1976	92,100	47,300	15,800	11,300
Difference (Projected - Actual)	3,300	3,300	1,700	1,900
Difference as Percentage of Projected	3.5%	6.5%	9.7%	14.6%
Slope of Long-Run Trend in Traffic Growth[b]	2.0%	2.4%	6.0%	8.4%
Number of Traffic Lanes in Each Direction	5	3[c] (or 4)	2[d] (or 3)	3
Average Daily Traffic per Lane	18,400	15,800 (or 11,800)	7,900 (or 5,300)	3,800

a. See accompanying text for explanation of traffic projections.
b. Average annual increase in daily traffic October 1969 - September 1973, expressed as a percentage of the mean traffic volume over this period.
c. The six lanes of the Golden Gate Bridge can either carry three lanes in each direction, or four lanes in one direction and two in the other.
d. The San Mateo-Hayward Bridge has two lanes in each direction on the approach causeways and three in each direction on the main span.

Source: Peat, Marwick, Mitchell & Co. analysis of traffic counts compiled by CALTRANS, Toll Bridge Administration, and Golden Gate Bridge Highway and Transportation District.

(where BART has had no effect). Expressed as a percentage of total traffic, the reduction on the Bay Bridge (3.5%) is by far the smallest of the four bridges.*

Explanation of Changes in Bridge Traffic Volumes

Six factors might explain the difference between actual and projected bridge traffic volumes over the period shown in Figure 16 through 19:

1. Changes in Underlying Growth Trends. The actual underlying traffic growth trends for the period from October 1973 onward might differ from the "long-run" trends estimated for the period from October 1969 through September 1973. This might arise either because of (1) changes in overall regional economic conditions (in which case, traffic growth on all four bridges would have changed in a similar way), or (2) differential population and economic growth patterns within the region.

2. Changes in Seasonal Patterns. The actual seasonal variation in traffic volumes could have changed since the 1969-1973 period used in estimating the trend-plus-seasonal model.

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*As discussed earlier, the difference between projected and actual traffic levels for the Bay Bridge appears to have decreased over the 2 years from October 1974 to September 1976. If only the 6 months following the start of transbay BART service are analyzed (instead of the 2 years summarized in Table 38), a slightly different picture emerges: the difference between projected and actual traffic volumes for the 6 months is 5,400 vehicles per day (5.9% of the total projected). But even this higher figure does not change the conclusion that the percentage reduction in traffic on the Bay Bridge is the smallest of all four bridges.

3. Gasoline Price Increases. The gasoline shortages of early 1974 and the associated increase in gasoline prices probably reduced traffic volumes of the four bridges in similar ways, although some differential impacts could result as a function of the purpose of travel.

4. BART. The start of transbay BART service in September 1974 was expected to make major reductions in automobile traffic on the San Francisco-Oakland Bay Bridge. Some minor impacts might also be expected on the San Mateo-Hayward Bridge as a result of Fremont-San Francisco travel diverting from the automobile to BART.

5. Induced or Diverted Traffic. Reductions in vehicle traffic volumes caused by diversion of travel to BART (or any other reason) could lessen traffic congestion and thereby cause new automobile trips (which would otherwise not have been made, would have been made to other destinations, or would have been made by different routes).

6. Other Factors. Among other factors causing changes in bridge traffic volumes are strikes by transit operators and changes in bridge tolls.

As shown in Figures 17 through 19, the differences between the actual and projected traffic volumes on the Golden Gate, San Mateo-Hayward, and Richmond-San Rafael Bridges have remained fairly constant from October 1974 onward. As pointed out, the difference for the San Francisco-Oakland Bay Bridge has been less constant. However, taking the evidence from the four bridges together suggests that the slopes of the trend lines and the month-to-month patterns of seasonal variation estimated for the period 1969 to 1973 have remained more or less constant since transbay BART began service. This constant pattern, in turn, suggests that, within the 2-year time frame considered (and subject to qualifications discussed below), the projections of the trend-plus-seasonal model provide a reasonable "without-BART" basis for explaining changes in bridge traffic volumes.

In the remainder of this section, the difference between actual traffic volumes and those projected by the trend-plus-seasonal model is analyzed in terms of the factors listed above. (The difference is sometimes referred to as a "reduction" in traffic volumes, although more strictly it is a shortfall relative to the prediction.)

Regression Analyses. Regression analyses were performed on data for each of the four bridges. For each bridge, the dependent variable is the difference between the actual average daily midweek traffic volume and the volume projected by the trend-plus-seasonal model (shown by the shaded areas of Figures 16, 17, 18, and 19). These variables represent the changes in bridge traffic volumes not explained by long-term trend and seasonal variations. Explanatory variables are defined to represent gasoline price (in constant 1967 prices); gasoline shortages (in January, February, and March 1974); the AC Transit strike (in July and August 1974); transbay BART ridership; and the Golden Gate Transit strike (in April, May, and June 1976).

For all four bridges, the regression models provide a convincing explanation of changes in traffic volumes in terms of the appropriate explanatory variables, and traffic volumes forecast using the regression model are close to actual traffic volumes.*

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*Details of the regression analysis are given in Reference 10, pp. 95-105.

Gasoline Shortage. In all four regression equations, the coefficient for the gasoline shortage variable is statistically significant and has the expected sign. The coefficients imply that the limited availability of gasoline in January, February, and March 1974 reduced bridge traffic by the following amounts: San Francisco-Oakland Bay Bridge, 5,000 vehicles per day (5.2% of average total daily traffic); Golden Gate Bridge, 2,400 vehicles per day (4.8%); San Mateo-Hayward Bridge, 700 vehicles per day (3.7%); and Richmond-San Rafael Bridge, 500 vehicles per day (3.7%). Bearing in mind the estimating errors inherent in the coefficients, the percentage traffic reductions are remarkably similar for the four bridges.

Transit Strikes. The regression coefficients for the variables representing the AC Transit strike in July and August 1974 are also significant and imply that traffic increased by 6,000 vehicles per day on the San Francisco-Oakland Bay Bridge as a result of the strike and by 1,900 vehicles per day on the San Mateo-Hayward Bridge. The regression coefficient for the variable representing the Golden Gate Transit strike in April, May, and June 1976 suggests that the strike increased Golden Gate Bridge traffic by about 1,900 vehicles per day.

Gasoline Price. Figures 16 through 19 all show that a marked decrease in highway traffic has coincided with increasing gasoline prices on all four bridges, and it seems reasonable to assume a cause-and-effect relationship between the two. This is corroborated by the results of the regression analyses, which show a statistically significant coefficient for the gasoline price variable for all four bridges.

On the San Francisco-Oakland Bay Bridge, the coefficient for gasoline price implies that a $0.01 increase (at 1967 prices) produces a traffic volume decrease of 540 vehicles per day, or 0.6% of the total traffic volume. The corresponding reductions on the other three bridges are:

Golden Gate Bridge, 490 vehicles per day (1.0%);* San Mateo-Hayward Bridge, 150 vehicles per day (0.9%); and Richmond-San Rafael Bridge, 180 vehicles per day (1.3%). Again, bearing in mind estimating errors, the coefficient values are similar for all four bridges when expressed as a percentage of the total traffic volume.

Population Growth Trends. As pointed out by another analysis of bridge traffic volumes (Reference 25), population changes in the central Bay Area counties have not been uniform over the 1970-1976 period considered in the regression analysis. Moreover, the 1973-1974 period when population growth was generally smallest (or population decline was greatest) coincides with the period when both gasoline prices increased and bridge traffic volumes declined. Thus, the population growth rate may explain some of the traffic shortfall. Unfortunately, the lack of reliable detailed population data precluded the inclusion of population as an explanatory variable in the regression analyses.

The significant coefficients obtained in the regression analysis for the gasoline price variable, and the consistency of the coefficient values among the four bridges (in different parts of the Bay Area), argue that higher gas prices have had a sustained effect on reducing traffic volumes. However, these regression results are inevitably based on correlations among the variables included in the analysis. Since a population variable was not included in the regression, the analysis does not address the possible influence of population growth on bridge traffic volume change. To the extent that population changes are correlated with changes in bridge traffic volumes (and gasoline prices), they may be an important factor, and gasoline prices may be correspondingly less important.

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*Golden Gate Bridge tolls increased from $0.50 to $0.75 in March 1974, at a time when gasoline prices were increasing. The toll increase was not included in the regression analysis as a separate explanatory variable, so it is likely that the toll increase effects are reflected in the gasoline price coefficient.

BART Ridership. In neither the Bay Bridge nor the San Mateo-Hayward Bridge regression equation does transbay BART ridership appear as a statistically significant explanatory variable. In other words, there is no identifiable correlation between reductions in total Bay Bridge traffic and the start of BART service that can be separated from the influence of gasoline price increases and other factors included in the regression.

Induced Traffic. Much of the apparent lack of BART impact on total Bay Bridge traffic volumes is probably attributable to the effects of induced traffic. Reductions in Bay Bridge traffic volumes resulting from the initial diversion of automobile trips to BART (and resulting from other factors, such as gasoline price increases) decreased traffic congestion on the Bay Bridge. This presumably allowed trips that were previously suppressed by the high levels of congestion on the bridge to be made more frequently or to be diverted from other destinations and routes. These presumed new trips have offset the capacity freed up by BART.

This reasoning is supported by the data given in Table 38, which point to the fact that the reduction in traffic has been proportionately smallest for those bridges on which the daily traffic volume is closest to capacity (and on which, therefore, the growth rate may have been slowed by capacity constraints).

San Francisco-Oakland Person-Trips by All Modes

This section focuses on person-trip volumes made by bus, BART, and private automobile in the San Francisco-Oakland Bay Bridge corridor in the 14-hour period from 6:00 a.m. to 8:00 p.m. (when BART carries nearly all its riders).

Projections of Historical Trends. Figure 21 shows average daily midweek westbound passenger trips in the San Francisco-Oakland Bay Bridge corridor. Included in these data are person-trips in private automobiles, in AC Transit and Greyhound buses across the bridge, and on transbay BART. Long-term trend and seasonal components of travel are apparent from the graphs.

Figure 21 also shows projections of total trips, automobile trips, and bus trips, which are based on a trend-plus-seasonal model similar to that used in the vehicle traffic analyses in the previous section. As before, it is assumed that the trend and seasonal travel patterns of previous years continue unchanged. The projected volumes are taken as the without-BART baseline against which actual traffic levels are considered to have increased or decreased in the 2 years from October 1974 to October 1976. The shaded areas of the figure highlight the differences between the actual and projected trip volumes.

Figure 21 shows the effects of the gasoline crisis in early 1974. Both automobile and total person-trips are well below projected levels, and bus ridership is slightly increased. The effects of the AC Transit strike in July and August of 1974 are also clear. Automobile person-trips were well above projected levels, and both transit and total person-trips were reduced drastically. Only Greyhound provided significant transbay transit service during the strike.

Changes in Automobile Person-Trips. Figure 21 shows that immediately after transbay BART service began, actual transbay automobile person-trips during the 14-hour day were below projected levels. Since then, however, actual and projected trip levels have generally differed very little; most recently, actual transbay travel by automobile has slightly exceeded projected travel. Apparently, the drop in automobile travel immediately after transbay BART began service has been offset by growth in travel for other reasons.

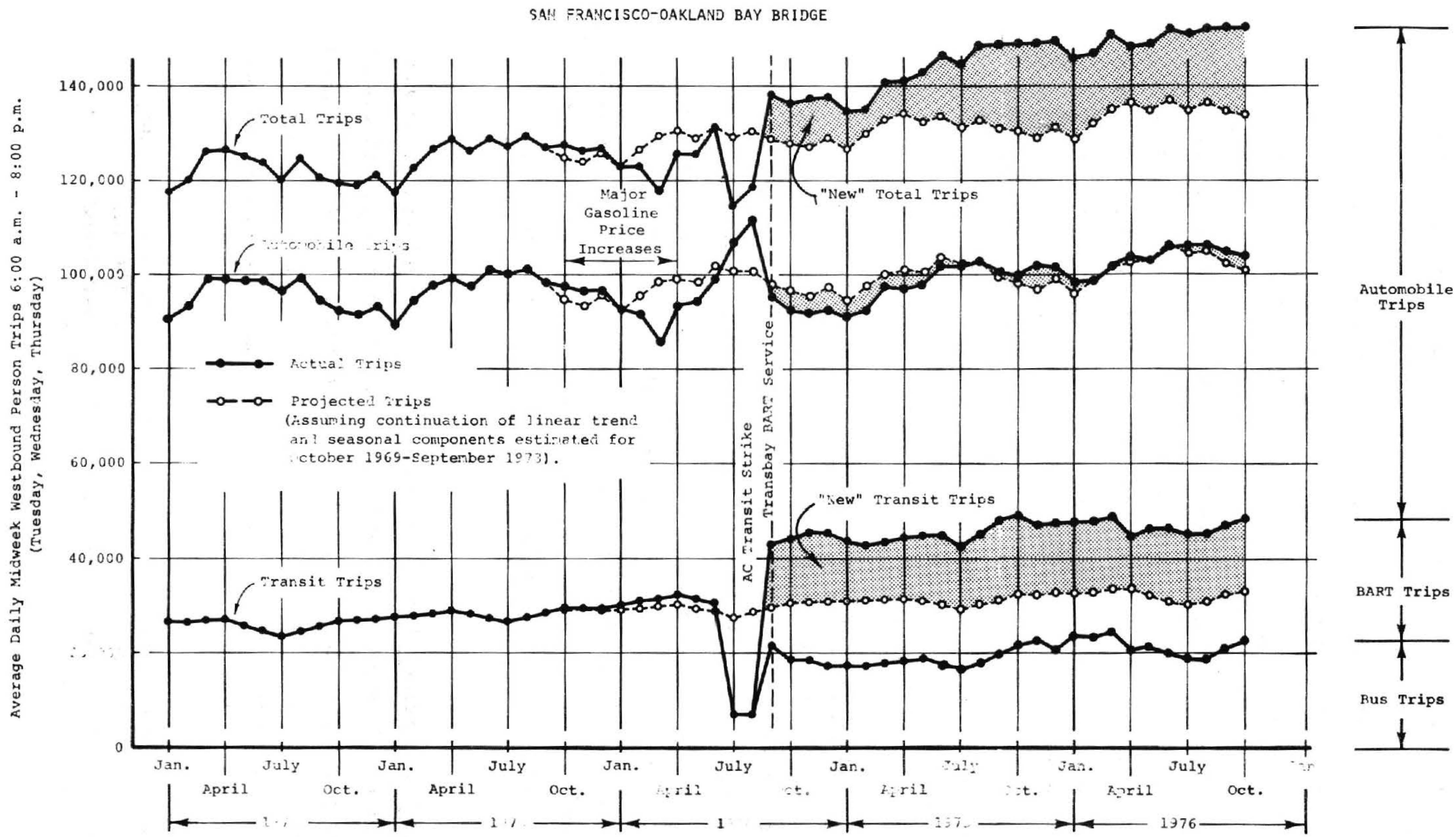

FIGURE 21

DAILY MIDWEEK PERSON-TRIPS IN THE SAN FRANCISCO-OAKLAND BAY BRIDGE CORRIDOR, JANUARY 1972 - OCTOBER 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Traffic and Patronage Counts Compiled by

- CALTRANS Toll Bridge Administration • University of California ITS
- BARTD • AC Transit • Greyhound Lines.

The trend projections of automobile person-trip volumes shown in the figure may be low estimates of likely without-BART volumes insofar as the data used to estimate the regression cover a period when automobile occupancies were lower than the period covered by the projection.* Thus, the projected-minus-actual shortfall in person-trips shown in Figure 21 is probably also a low estimate for the period of the projection (relative to the estimated shortfall in vehicles volumes shown in Figure 16). If the projected automobile trip volumes are adjusted to account for the change in automobile occupancy, actual automobile travel is estimated to average about 4,000 person-trips per 14-hour day less than the without-BART projection over the 2 years, October 1974 to September 1976. (This corresponds to the estimated 3,300 vehicle-trips per 24-hour-day reduction in Bay Bridge traffic given in Table 38.)

Changes in Transit Person-Trips. Compared with projections of bus travel, transbay BART service increased transit ridership by over 40%. Over the 2 years after transbay BART opened, BART ridership averaged 26,000 trips per day in each direction, and bus ridership averaged about 20,000 trips per day. These total 46,000 trips, compare with an average of 32,000 trips projected by the trend-plus-seasonal model of bus travel alone. The difference between the two, 14,000 trips per day, constitutes "new" transit ridership attracted at the start of transbay BART service. These new trips are shown as a shaded area in Figure 21.

Changes in Total Person-Trips. A comparison of actual and projected trip volumes for the 2 years after BART opened shows an average difference of 10,000 trips per day by automobile and transit combined (145,000 actual trips compared to 135,000 projected trips). The difference represents new trips, which, according to the assumptions of the trend-plus-seasonal

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*There is no reason to attribute this increase in automobile occupancy to BART; in fact, the reverse effect is more likely. The increase more probably results from the active promotion of carpooling on the Bay Bridge by providing toll-free carpool-only lanes.

analysis, would not have been made had the opening of transbay BART (and possibly other events) not occurred.

Modal Distribution of Person-Trips With and Without BART. Table 39 summarizes the pattern of midweek daytime transbay travel. The average daily number of person-trips made by automobile, bus, and BART in the 2 years after transbay service began is compared with the number of trips that would have been made (hypothetically) if BART had not been operating. The bases for the without-BART estimates are the trend-plus-seasonal projections.

Two further assumptions were made in constructing the table: (1) no significant diversion of travelers to buses resulted from the opening of BART and (2) no significant diversion occurred from buses to automobiles. Numbers in the table are approximate, reflecting the need to balance the various estimating errors involved, but in all cases they are close to the corresponding actual or projected figures.

According to the analysis summarized in Table 39, of the average daily transbay person-trips made over the 2 years since transbay BART began, approximately 10,000 probably would not have been made had BART not started transbay service. Of these, no more than 2,000 were made on BART itself. The remaining 8,000 new trips were made by automobile. These 8,000 person-trips correspond to something over 5,000 vehicle-trips, or around 6% of the total vehicle-trips typically using the Bay Bridge between 6:00 a.m. and 8:00 p.m. Clearly, this estimate is subject to considerable uncertainty given the many factors influencing travel volumes. The actual number of new automobile person-trips could be lower or higher. However, there is some basis for arguing that the 8,000-trip estimate is reasonable. Since the projected 103,000 automobile person-trips do not account for the effects of gas price increases, Bay Bridge capacity constraints, or possible changes in the population growth rate, the projection is more likely to be high than low. Correspondingly, the 8,000-trip estimate is likely to be low rather than high.

Table 39

MODE OF TRANSBAY TRAVEL WITH AND WITHOUT BART
Average Daily Midweek Westbound Person-Trips
October 1974 to September 1976
(6:00 a.m. to 8:00 p.m.)

	Mode of Travel With BART			Total Trips Projected
	Automobile	Bus	BART	Without BART
Mode of Travel Without BART				
Automobile	91,000	--	12,000	103,000
Bus	--	20,000	12,000	32,000
No Trip Made	8,000	--	2,000	10,000
Total Trips Actually Made With BART	99,000	20,000	26,000	145,000

Reading down each of the four columns shows the number of trips actually made by automobile, bus, BART, and in total, respectively, distributed according to the mode that would be used, hypothetically, without BART. Included in the distributions are trips which it is estimated would not be made at all without BART. For example, reading down the third column of the table shows that, of the total of 26,000 trips actually made by BART, 12,000 would be made by automobile if BART were not available; 12,000 would be made by bus; and 2,000 would not be made at all.

Equivalently, reading across each of the first three rows shows the number of trips that it is estimated would be made, if BART were not available, by automobile, bus, or not at all, respectively, distributed according to the mode actually used. For example, reading across the first row of the table shows that, of the total estimated 103,000 person-trips which would be made by automobile if BART were not available, 91,000 are actually made by automobile, and 12,000 are actually made by BART.

The fourth row of the table shows the number of trips actually made by automobile, bus, BART, and in total, respectively.

Source: Peat, Marwick, Mitchell & Co.
(See accompanying text for derivation.)

The analyses described herein do not permit a definitive explanation of the sources of these 8,000 apparently new automobile person-trips. But it seems reasonable to conclude that a large proportion of the new automobile trips on the Bay Bridge have been induced by the changes in travel conditions brought about by BART. Some portion of the new trips may have diverted from the San Mateo-Hayward Bridge, but the evidence given earlier in this chapter suggests that this diversion has been small. Most of the new trips probably would not have been made across the Bay Bridge (or would have been made less frequently) without BART. These may be entirely new trips or trips previously made between locations on one side of the Bay.

As shown in Table 39, about 12,000 transbay person-trips by automobile have been diverted to BART (the equivalent of about 8,000 vehicle-trips). Apparently, about 8,000 automobile person-trips have been induced (the equivalent of about 5,000 vehicle-trips). Taken together, these numbers imply a net decrease of about 4,000 automobile person-trips (about 3,000 vehicle-trips) between 6:00 a.m. and 8:00 p.m. This result is consistent with the results of the analyses of Bay Bridge vehicle traffic volumes summarized in Table 38.

Some part of the 3,000-vehicle reduction can probably be attributed to increased gasoline prices (and possibly changes in population growth rates). But even if the effect of gasoline price is discounted, and all the reduction is attributed to BART, BART's effect is small when viewed in the context of other factors influencing traffic levels. Bay Bridge vehicle traffic has been increasing at an average annual rate of nearly 2,000 vehicles per day for several years. Typically, average daily traffic may be as much as 4,000 vehicles per day above or below the annual mean at different times of the year because of seasonal variations. Variation among days of the week is also such that there is often a difference of over 10,000 daily vehicles between the highest weekday and the lowest weekday.

In the context of these sources of variation in traffic volumes, a net reduction in traffic of around 3,000 vehicles per day is significant, statistically speaking, but nevertheless small in relation to the total volume of transbay travel. The reduction in automobile travel attributable to BART represents about 1 or 2 years of historical growth in Bay Bridge travel and is of the same order as normal week-to-week variations in traffic.

San Francisco-Oakland Bay Bridge Traffic Congestion

The changes in transbay automobile traffic discussed in the preceding sections have been accompanied by changes in travel times and congestion levels on the Bay Bridge. These are discussed in this section.

Bay Bridge Peak-Period Travel Times. Figure 22 summarizes the results of two morning peak-period travel time surveys conducted across the Bay Bridge. The first (pre-BART) survey was conducted in April 1974, and the second (post-BART) survey was conducted in May 1975. Transbay BART service started in September 1974.

The relatively short period between the "before" and "after" data sets, and the fact that they were collected at about the same time of the year, means that the differences between the two graphs in Figure 22 may be attributed to BART with some confidence. However, the effects of the gasoline crisis complicate the picture. In April 1974, traffic levels may have been depressed in the aftermath of gasoline shortages in February and March, and by accompanying price increases.

Figure 22 shows that peak-period travel times over a 3.2 mile section of the Bay Bridge in May 1975 were about 1.5 minutes shorter than in April 1974. This represents an increase in overall average speed from about 16 to 18 miles per hour at the most congested time. The most congested part of the peak period has shortened and shifted to a slightly later time; the figure shows a shift of about 15 minutes (from 7:30 a.m. to 7:45 a.m.).

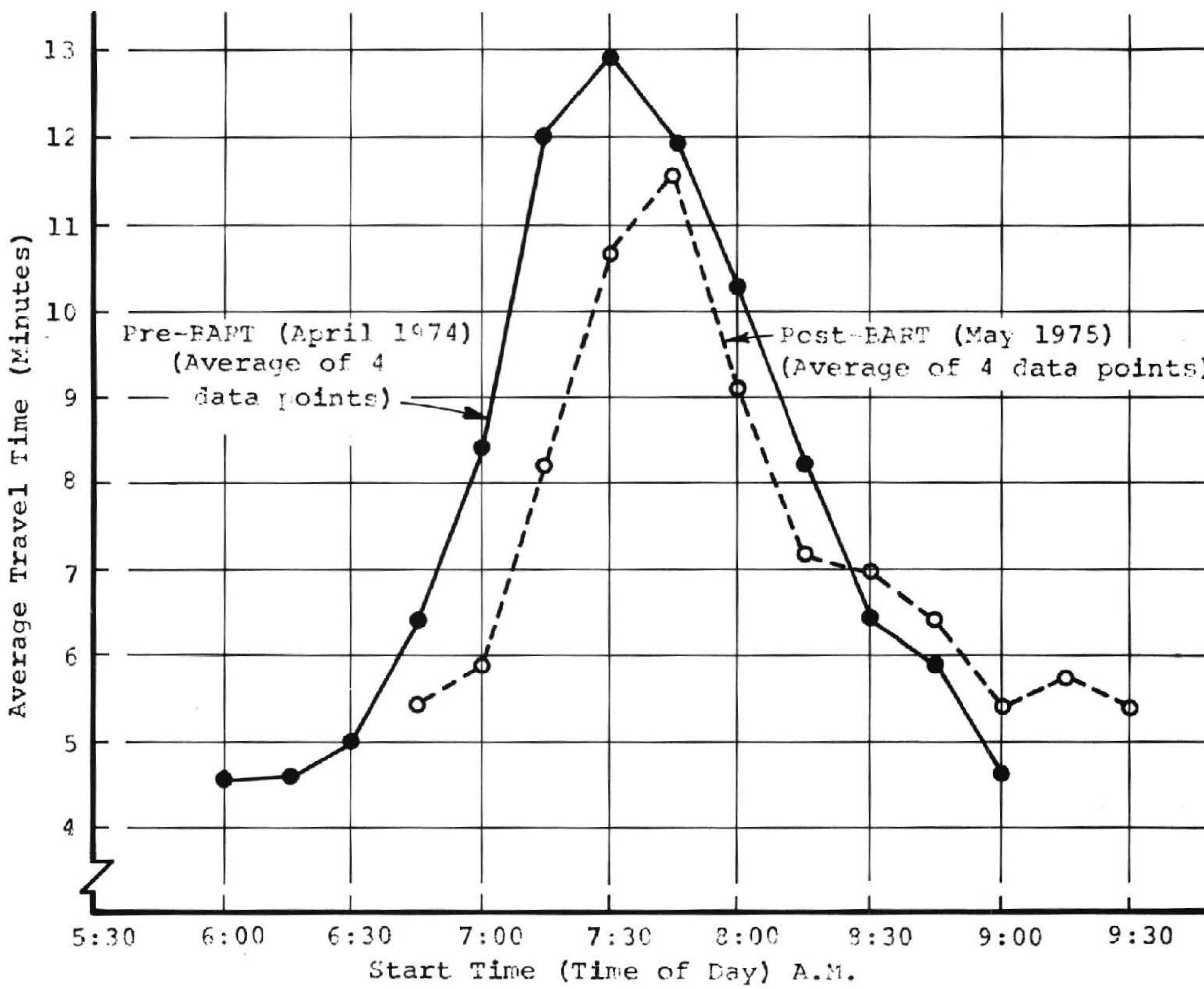

FIGURE 22

MORNING PEAK-PERIOD TRAVEL TIMES ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE

Note: Travel times are for westbound travel over a 3.2 mile section of the bridge starting before the toll plaza.

Source: CALTRANS and BART Impact Program, Moving Car Observer Travel Time Surveys.

Bay Bridge Metering System. A set of data that allows more confident conclusions on how BART has influenced traffic congestion are the records of the metering system used to control traffic flows on the Bay Bridge. Since March 1974, westbound traffic entering the five lanes of the San Francisco-Oakland Bay Bridge has been metered. The flow of traffic leaving the 17 toll-booth lanes is controlled by a red or green traffic light above each lane before the pavement merges into five lanes at the beginning of the bridge structure itself. The traffic lights are operated automatically by detectors that monitor the rate of flow of vehicles entering the bridge. At free flow rates, all lanes show a green light.

The metering system is activated (and shows periodic red lights above lanes) when the traffic flow rate increases above a specified level, indicating reduced speeds and a buildup of congestion on the bridge. Thus, the starting time and duration of metering-system operation are interesting measures of congestion on the Bay Bridge for which data are available on a continuing and consistent basis. Figures 23 and 24 show the times of system activation during the morning peak period for Tuesdays, Wednesdays, and Thursdays, day-by-day from March 1974 until August 1976. Gaps indicate days for which data are not available.

Figures 23 and 24 show a fairly consistent pattern of traffic congestion from March to June 1974, with day-to-day variations about the norm caused by weather, traffic accidents, and other influences. The starting time and duration of the metering period, and the day-to-day variations in its duration all changed dramatically in July and August of 1974, giving a clear picture of the traffic congestion caused by the AC Transit strike in those 2 months. The period of activation then decreased in September when transbay BART service began. But since then, it appears to have increased back to higher levels. By late 1975, it had increased to a level close to that of early 1974; and by early 1976, it was considerably longer than in 1974.

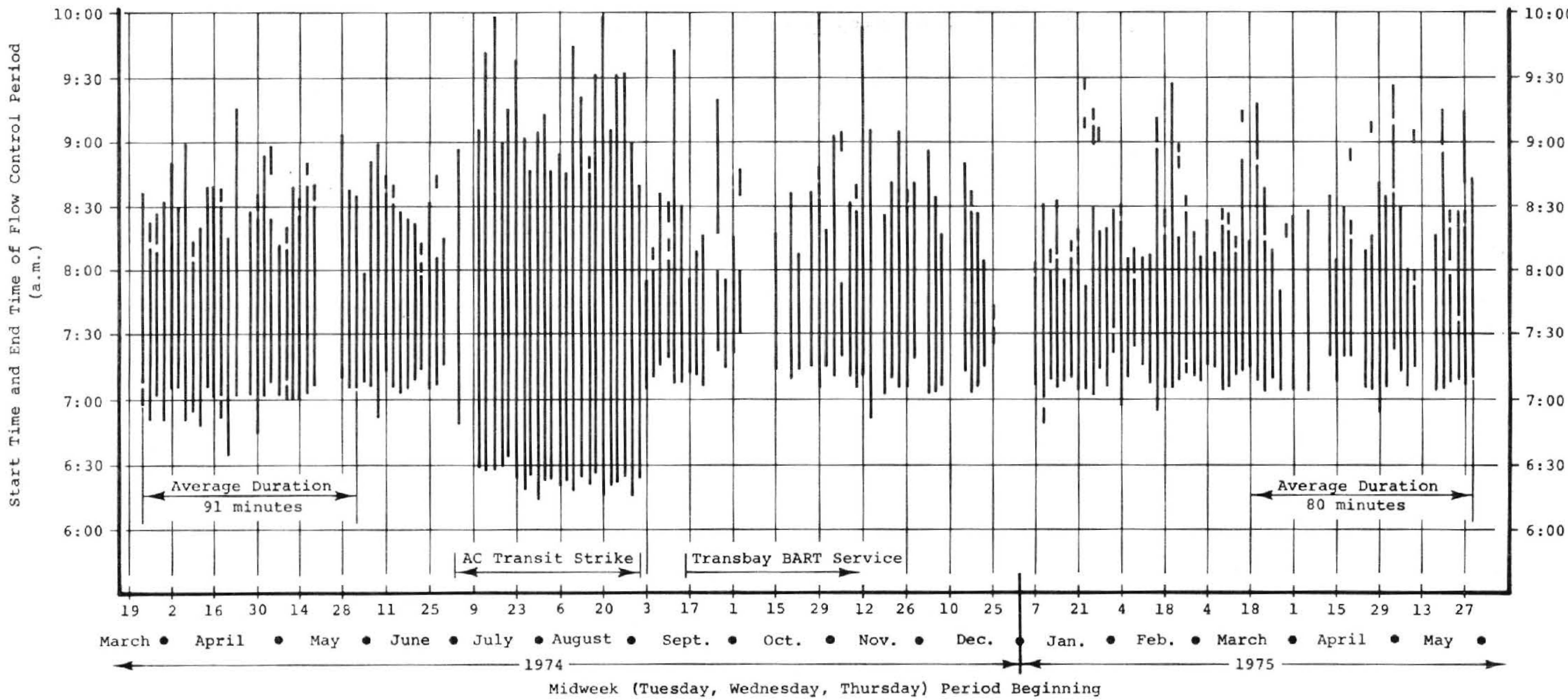

FIGURE 23

TIMES OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM
TUESDAYS, WEDNESDAYS, AND THURSDAYS, MARCH 1974 - MAY 1975

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

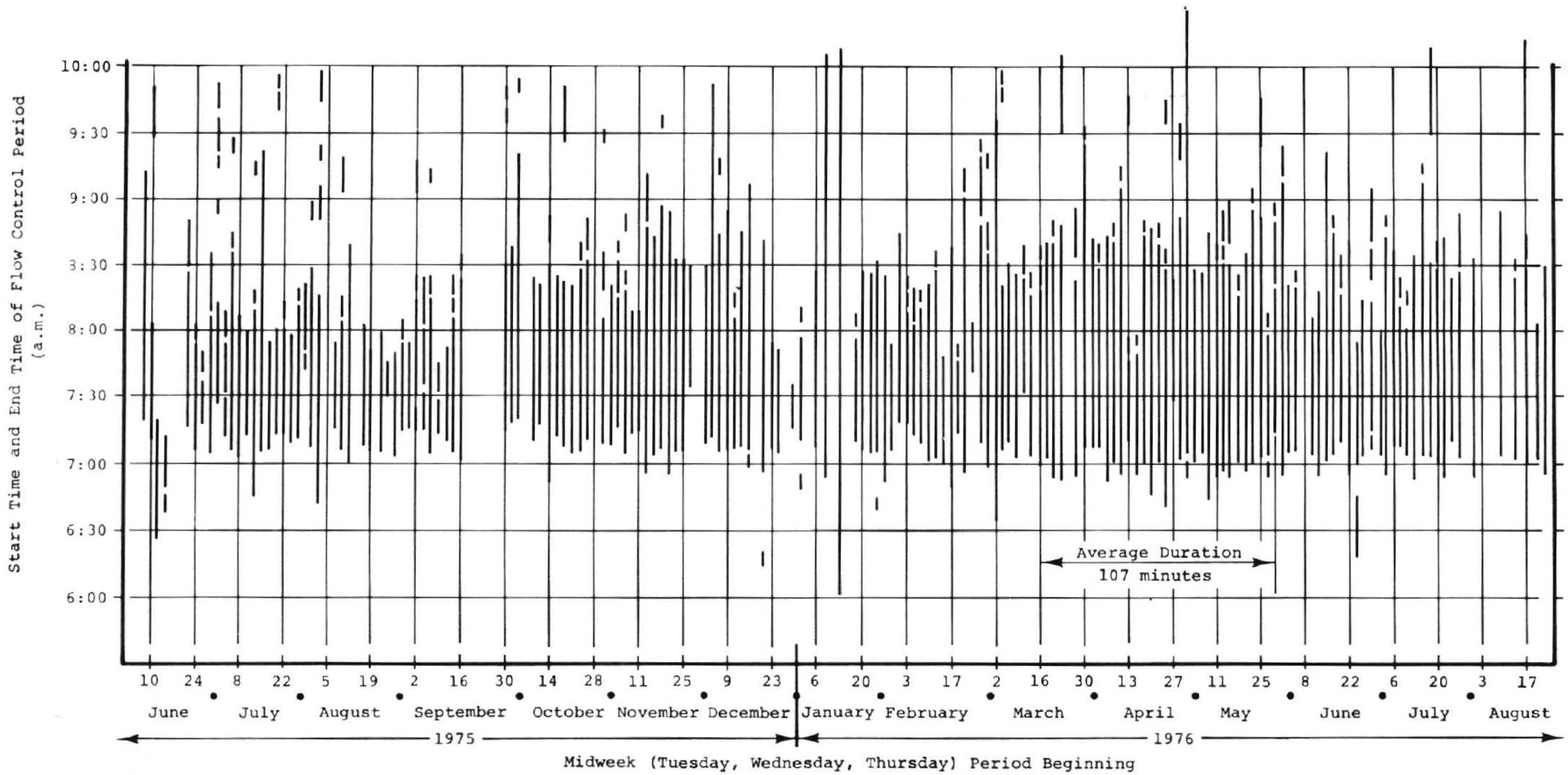

FIGURE 24

TIMES OF ACTIVATION OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE TRAFFIC METERING SYSTEM

TUESDAYS, WEDNESDAYS, AND THURSDAYS, JUNE 1975 - AUGUST 1976

Source: CALTRANS Toll Bridge Administration, Daily Records of Bay Bridge Metering System.

Comparing the 11-week period (mid-March to end of May) in 1974 following the start of metering-system operation with the corresponding period in 1975 (about 6 months after transbay BART started) shows that the period over which the metering system operated started 10 minutes later (7:09 a.m. on average in 1975 compared with 6:59 a.m. in 1974) and had a shorter duration (80 minutes in 1975 compared with 91 minutes in 1974). Both of these differences are statistically significant at the 5% level.

Looking at the corresponding (mid-March to end of May) period in 1976, the average start time was 7:02 a.m., and the average duration of flow control had increased to 107 minutes. Statistical tests show that the start times in 1974 and 1976 are not significantly different. However, the durations of flow control are quite different; the period in 1976 is significantly longer than in 1974 or 1975.

Thus, both the travel time and metering system analyses point to the same conclusion with regard to changes in traffic congestion on the Bay Bridge. Measurable reductions in traffic congestion occurred immediately after transbay BART began service (and the busiest periods appear to have shifted to slightly later times of day), but the reductions were small relative to total travel times. Moreover, 2 years after service began, whatever reductions in congestion BART may have achieved had evaporated as a result of increased traffic volumes.

Caldecott Tunnel Travel

Average daily westbound person-trips at the Caldecott Tunnel between the hours of 6:00 a.m. and 8:00 p.m. are plotted on Figure 25. As noted in Chapter III, the Caldecott Tunnel is a key section of Route 24 which closely parallels the BART Concord Line. Included in the Figure 25 data are trips by persons in private automobiles, BART, and Greyhound buses.

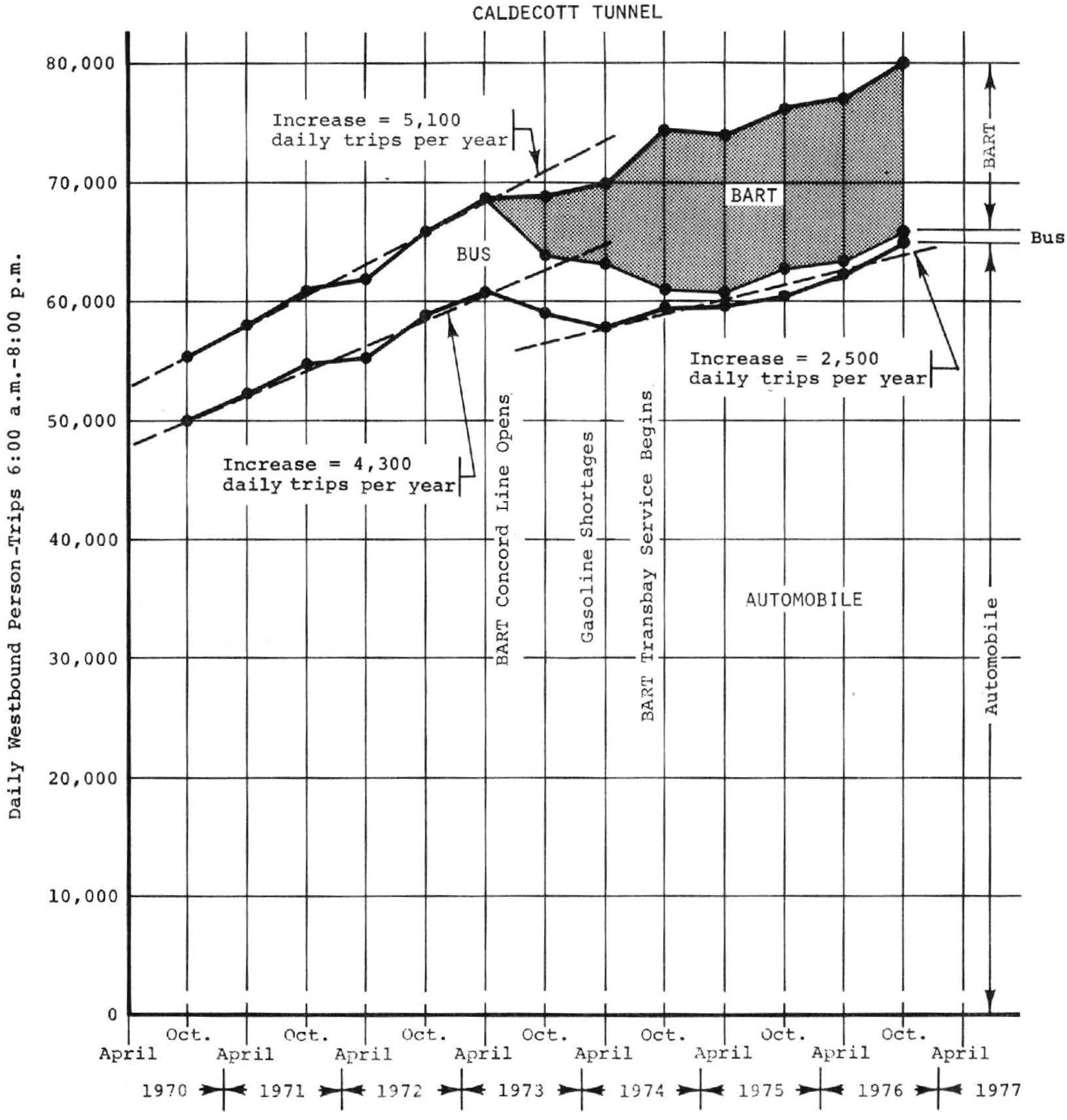

FIGURE 25

DAILY MIDWEEK PERSON-TRIPS IN THE CALDECOTT TUNNEL CORRIDOR
OCTOBER 1970 - OCTOBER 1976

Source: Peat, Marwick, Mitchell & Co. Analysis of Data Collected by University of California, Institute of Transportation Studies.

Since traffic volumes in April and October are both typically close to the annual means, seasonal variations are not evident in the graph. However, long-term trends are apparent; both automobile person-trips and total person-trips (automobile and bus combined) increased steadily over the period to April 1973. Automobile person-trips decreased in October 1973, probably because of the opening of BART's Concord Line, and again in April 1974 because of gasoline shortages and price increases. When gasoline again became freely available, automobile trips resumed an increasing trend (which was apparently unaffected by the start of transbay BART service). But, perhaps because of the presence of transbay BART and the residual effect of higher gasoline prices, the rate of increase appears to be lower than before (although the difference in rates is not statistically significant).

Travel by bus was fairly constant from October 1970 to April 1973, but it dropped following the opening of BART's Concord Line and the start of transbay BART service. However, this reduction has clearly been compensated for by travel on BART.

Extrapolation of the pre-BART automobile trip trend line shown in Figure 25 suggests that, had other factors remained unchanged, 14-hour westbound automobile person-trips in April 1974 would have totaled approximately 64,500, or 6,900 more than the actual level of 57,600. This lower actual level is attributable to the gasoline shortage and price effect as well as the start of BART Concord Line service, and possibly other factors. It represents a shift in the growth of automobile trips of about 1 to 2 years. Again, the appearance of induced trips in the often-congested Caldecott Tunnel corridor may have offset BART-caused reductions in automobile trips.

Conclusions

This chapter has focused on traffic crossing the San Francisco-Oakland Bay Bridge. BART's impacts on this Bridge traffic have probably been greater than on any other single highway link. Nevertheless, BART's net impacts on Bay Bridge traffic volumes have been so small as to be very difficult to detect with confidence, given the many other sources of variation in traffic volumes. This is the case even though an unusually high-quality time-series data set is available as the basis for analysis. Similarly, for the Caldecott Tunnel, where BART might be expected to have had significant effects on traffic, BART's impacts are difficult to detect. On other major highways paralleling BART, such as I-280 which more or less parallels the Daly City Line, available traffic data do not allow BART's impacts to be isolated.

No attempt has been made to assess BART's impacts on areawide traffic volumes and congestion explicitly in this study. However, the relatively small impacts found for the major corridors analyzed suggest that BART's impacts on aggregate areawide traffic volumes and congestion have almost certainly been so small as to be undetectable given the many other factors influencing traffic.

The predictions of BART's proponents were that, without BART, increasing highway travel volumes would create intolerable traffic congestion and thereby stifle growth and economic activity in the central business districts of San Francisco and Oakland. The San Francisco-Oakland Bay Bridge was one of the key travel corridors the planners had in mind. BART was conceived and planned as a means of averting this by providing increased transportation capacity and attractive transit service that would remove significant volumes of automobiles from the highways. Thus, highway congestion would be reduced, making commuting to the downtown areas easier, and allowing growth in the number of work trips to the downtowns.

BART's small apparent effect on highway traffic volumes and congestion stems in part from its lower-than-predicted ridership. The low ridership, combined with the relatively high diversion of trips from bus to BART rather than from automobile, has caused fewer automobiles to be removed than predicted.

But more significant is that new automobile trips have appeared to fill the road space freed by the diversion of trips to BART. These new trips may be trips that would not have been made at all, or trips that would have been made to different destinations (for example, alternative shopping destinations), given without-BART levels of traffic congestion. In either case, they can be regarded as "induced" automobile trips for the highway or corridor in question (although not all represent induced trips on the transportation network as a whole). In addition, induced trips are now being made on BART itself. Thus, BART has had the effect of allowing (and encouraging) more trips to be made both by transit and by automobile. These new trips represent gains in mobility and welfare to the people making them.

BART has had the obvious effect of increasing transport capacity in the Bay Bridge corridor (and has the potential for increasing capacity further still). But because the corridor was heavily congested before BART began service (evidencing an excess of travel demand over supply), the addition of BART's capacity has encouraged more transbay trips to be made, with the result that traffic volumes and congestion have been reduced only minimally. This phenomenon can be expected to occur whenever transport capacity is added in a capacity-constrained corridor and no brake on demand is applied, whether the additional capacity is provided by a rapid rail line, or freeway, or any other facility. In planning and predicting the impacts of such facilities, careful attention must be given to estimating the likely volume of induced travel and the extent to which relieving highway traffic congestion is an attainable objective.

BART's impacts on traffic and congestion are inevitably judged relative to expectations: BART's impacts are small relative to widely held expectations about what BART would achieve (as publicized by early proponents of the System in particular). But, by and large, these expectations were unreasonably optimistic, especially with regard to BART's ability to affect traffic congestion significantly. Had a more modest (and realistic) set of expectations formed the basis for judgment, BART's impacts now might not generally be considered so small.

IX. IMPLICATIONS

The principal conclusions of this study with regard to BART's ridership and particular kinds of impacts are given at the end of each of Chapters IV through VIII. The purpose in this chapter is not to restate all these conclusions, but instead to point out implications for planning urban rail transit in future.

Applicability of Findings

In drawing implications from the study for the planning of rail rapid transit systems elsewhere, it is important that the findings be viewed in proper context.

BART was conceived and planned to meet specific objectives, primarily to benefit long-distance commuters to the downtown employment centers of San Francisco and Oakland. Objectives such as conserving fuel, controlling air pollution, or improving the mobility of disadvantaged segments of the population, which are held as important objectives of many present-day public transport improvements, were not emphasized in BART's planning. In drawing conclusions from the BART experience for other areas, both the original BART intents and the current planning objectives of the other areas should be kept in mind.

The geography, institutions, and established transportation system of the San Francisco Bay Area, of which BART has become a part, are of course different in many ways from the urban structure of other areas where rail systems are now being considered or developed. At the same time, the Bay Area--with its central-city employment concentrations, older inner-city residential areas, newer distant suburbs, and freeways congested by commuter traffic--has much in common with other large American urban areas. In attempting to apply conclusions about rail transit impacts elsewhere, both the differences and the similarities of the areas must be taken into account.

In this study, BART was evaluated against the hypothetical alternative transportation system judged most likely to have evolved without BART--in effect, a "do-nothing" alternative. BART's impacts relative to those which might have resulted from a high-quality bus system, increased highway construction, or other investments that might currently be under evaluation as alternatives to rail systems in other urban areas, were not analyzed.

The study has documented BART's impacts over the 5-year period since service began, given actual BART service levels and available transportation alternatives. No attempt was made to project what BART's impacts might be in the future under different circumstances.

For all these reasons, conclusions from this BART study should be applied to other areas and in other circumstances with caution. In particular, it will be necessary to appreciate how the characteristics of BART, its setting, and the assumptions underlying this study relate to other areas and circumstances. Nevertheless, the findings of this study regarding BART's impacts on travel in the Bay Area have significant implications for those now considering or planning investments in rail rapid transit systems in other urban areas.

Implications for Planning Rail Transit

BART's impacts on transportation and travel patterns have generally been smaller than expected by its planners and proponents. But this reflects as much or more on the optimism of the expectations as it does on BART's performance.

Ridership Volumes. Although BART's current ridership of 140,000 trips per day represents a highly significant volume of travel, especially in certain key corridors, it is well below the 260,000 trips per day originally predicted by its designers. This shortfall is explained in part by the shortcomings of current BART service. As the level and reliability of service improves, increases in ridership can be expected. But, even so, it seems unlikely that the original estimates will be achieved as a result of feasible near-term changes in BART service.

The BART experience shows that attracting people to a rail transit system like BART, especially those who would otherwise drive their cars, depends primarily on providing frequent, fast, and reliable service, and convenient access to the rail transit stations. The appearance, comfort, and other qualitative aspects of BART service, though appreciated, are of secondary importance to most travelers.

But the ability of a rail transit system like BART to attract ridership (insofar as this ability is determined by the door-to-door travel times that can be provided), is limited. Even under ideal service conditions, it is necessary for people to get to and from the train station, transfer between vehicles, and wait for trains. Those who are responsible for estimating travelers' mode choice decisions and ridership volumes on another rail system must be careful to make realistic assessments of the level of service that can be provided in practice, and to recognize the intrinsic constraints on the ability of rail transit to attract riders.

Share of Travel. Although BART was intended to be a regional rapid transit system and was largely paid for by people throughout the central Bay Area, BART's share of all trips made areawide is relatively small, amounting to 2% or 3%. Its impacts on areawide vehicle-miles of highway travel and related impacts on fuel consumption and exhaust pollution, are correspondingly small. But these small impacts are all that might reasonably be expected: BART, having only 71 miles of track, should not be expected to have major impacts on an urban area of 330 square miles and a population of 2.6 million people. In this regard, it should be acknowledged that even if BART's ridership were much higher, say at the level of 200,000 trips per day currently targeted by the BART District for long-range future service levels, its areawide impacts would probably not be noticeably different from those so far achieved.

Rather, BART has captured a significant share of trips and has had measurable impacts in a few well-defined travel corridors and for certain kinds of trips. Again, a lesson for other areas is the importance of establishing and publicizing realistic expectations about what a rail system can and cannot achieve, given the complex travel patterns of an established urban area. Realistic estimates of impacts are needed not only by transportation planners and designers, but also by the public and others who must make decisions about the investment of public funds in rail transit.

Highway Traffic Volumes. Even where BART's share of travel is greatest--specifically in the transbay travel corridor--BART has had an apparently small net impact on highway traffic. Perhaps half of all BART's 30,000 daily transbay trips in each direction would otherwise be made by automobile. Thus BART has clearly changed patterns of travel by automobile across the Bay Bridge. BART has also obviously increased total transport capacity in the Bay Bridge corridor. But because the corridor was heavily congested before BART began service (evidencing an excess of travel demand over supply), induced automobile trips have offset those diverted to BART. Thus, BART has allowed or encouraged more transbay trips to be made, (thereby benefiting the people making the new trips), with the result that the net change in highway traffic volumes and congestion is very small when with-BART and hypothetical without-BART alternatives are compared.

This conclusion, too, raises the issue of what impacts should be expected from the introduction of new rail transit capacity. The phenomenon of induced traffic should be expected to occur whenever transport capacity is added in a capacity-constrained corridor and no brake on demand is applied, whether the additional capacity is provided by a rapid rail line, a freeway, or any other facility. In planning and predicting the impacts of such facilities, careful attention must be given to estimating the likely volume of induced travel, and the extent to which relieving highway traffic congestion is an attainable objective. Again, it is important that realistic assessments of impacts be made available not only to those responsible for planning and design, but also to the public and other decision makers.

Rail-Bus Coordination. An issue of concern in planning rail transit systems is the best way in which new rail services can be coordinated with the existing network of bus lines. In attempting to draw implications from the BART experience for planning rail-bus coordination in other areas, it is especially necessary to pay attention to differences and similarities between transit operations in the Bay Area and those in other areas. However, it is clear that in the Bay Area, the start of BART service has not caused major disruptions to established bus operations. Insofar as the BART experience is applicable to other areas, it suggests that modification of an existing network of bus routes to accommodate the start of rail service may best be achieved gradually by incremental service changes as the patterns of demand for access to the rail system emerge, and as bus capacity is made available from cutbacks in line-haul service where ridership is lost to rail.

In some cases, proposals for service reductions were prevented or delayed by public protest. In other cases, the lower-than-expected cutbacks stem from the slow response of the bus system managers to changes in demand. For the most part, however, the level of service cutbacks simply reflects the reduced level of demand. Although BART effectively offers a parallel service to some bus lines, many people continue to use the bus because the bus offers faster, cheaper, or more reliable service for their journeys. Bus service changes also reflect BART's offsetting influences on the demand for parallel and feeder services. Many bus lines serve both riders who use the bus as an alternative line-haul mode to BART and those who use the bus as a means of getting to and from BART stations.

In the Bay Area, no single authority is empowered to require cutbacks in bus services that apparently duplicate BART, or to direct any other change in service, such as providing new feeder bus service. Changes in services instead have resulted from more-or-less independent adjustments made by the various operators in response to changes in demand. Consequently, the BART experience cannot directly address the advantages and disadvantages of pursuing a policy of "forced" rail-bus coordination, as might be proposed in another area with a different set of institutional constraints.

However, the analysis of BART impacts does show that, except in the few cases where the train exactly duplicates or improves bus service, many people continue to use the bus in preference to BART. An implication is that removal of apparently parallel bus service will, in many cases, remove the availability of the preferred travel alternative, and hence reduce the mobility, of significant numbers of travelers. In planning future systems, these losses in traveler mobility need to be weighed carefully against the cost savings that might be achieved. The overlapping nature of parallel and feeder demand further complicates the question of what level of bus service should be provided.

Potential Impacts of Rail Transit

Although it was not the purpose of this study to speculate on what BART's impacts might be in the future, or under different conditions of transportation supply and demand, it is evident that many of BART's impacts would be greater if ridership were higher. BART is likely to be most successful in attracting more riders from the bus and automobile by improving reliability and reducing travel times, particularly the time people must spend waiting for and transferring between trains.

BART service is improving and is likely to continue to improve as direct Richmond-Daly City service begins, as headways are reduced, and as reliability is increased. Improved feeder bus services would also decrease access times for some people, and enlarged car parking lots at BART stations would improve access for others. All these improvements would increase BART ridership.

However, large improvements in overall door-to-door BART travel times are indicated as being necessary to achieve significant increases in ridership. For example, analysis of transbay travel mode choices suggests that a 10% reduction in the door-to-door travel time for the average trip by BART--which at 6 minutes implies a substantial improvement in effective BART station-to-station travel times--would increase ridership by something like 5%, other factors remaining unchanged.*

In a related analysis of transbay survey data, the sensitivity of BART ridership to hypothetical changes in station spacing was assessed by considering the offsetting effects of different station spacings on the time travelers must spend getting to and from stations, and the time they must spend on the trains. Again, it was concluded that

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*This analysis is reported in Reference 12, pp. 85-94.

other things remaining unchanged, effects on BART ridership would be small had BART stations been built closer together or farther apart.*

Thus, BART's ridership is largely constrained by the intrinsic limitations of the service it can provide, particularly the requirement that most people must transfer between vehicles in the course of their journeys. Even in combination with improved BART reliability and access facilities, feasible improvements in BART door-to-door travel times would probably not increase BART ridership by enough to change the impacts described in this report in a significant way.

However, the conclusion that only modest increases in BART ridership are likely to result from feasible improvements to BART service is based on several implicit assumptions. For example, it is assumed that land use patterns do not change drastically; also that the availability, price, and service offered by bus and automobile remain at approximately their current levels.

Future increases in BART's ridership may depend as much on reductions in the service offered by the automobile as on improvements to BART service. These reductions may result "naturally" from increasing traffic congestion; or they may result from causes such as increased gasoline prices; or they may result from explicit actions taken by transportation decision makers to regulate the price or supply of alternative modes (for example, by increasing road use tolls or restraining driving in other ways).

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*This analysis is reported in Reference 12. Two case studies were considered: transbay travel from (1) the 6 stations on the Concord Line and (2) the 10 stations on the Richmond Line and northern part of the Fremont Line. On the Concord Line, residential development is low, the automobile is the dominant mode of access to BART, and station spacing is high (3.5 miles on average). Hypothetical station spacings between 5.8 miles and 2.2 miles were analyzed. For the Richmond and Fremont Line stations, residential densities are higher, most people walk or take the bus to BART, and BART station spacing is lower (2.0 miles on average). Hypothetical spacings between 2.6 miles and 1.5 miles were analyzed. None of the alternatives showed more than a 2% increase over current ridership.

As noted earlier, BART cannot be expected to achieve many of the impacts claimed for it at any likely ridership level. But a potentially high-quality transit system such as BART can have a significant effect on increasing transit use and reducing automobile use in specific travel corridors, especially if accompanied by changes in the price and availability of alternative modes. For example, the existence of BART may permit the transportation decision maker to take actions to restrain private car use that would not be practicable without BART. Potentially, BART's most important impact may be the flexibility it allows for planning and operating transportation in the Bay Area in the future.

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19. The Impact of BART on Local Transit Service and Financial Policy, BART Impact Program Document No. DOT-BIP-WP 42-8-77, Booz, Allen & Hamilton, Inc., March 1978.

Many other reports have been produced by the BART Impact Program in addition to those referenced in Lists A and B above. Most are available through the National Technical Information Service, Springfield, Virginia 22151. Others, documenting details of survey procedures, data sets, and analysis methodologies are available from the Metropolitan Transportation Commission, Hotel Claremont, Berkeley, California 94705. Queries regarding the availability of reports should be addressed to the Metropolitan Transportation Commission.

C. OTHER REPORTS REFERENCED

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